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DEPARTMENT OF AGRICULTURE AND LABOR
INSULAR EXPERIMENT STATION
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REPORT OF THE DEPARTMENT OF PATHOLOGY AND BOTANY.

[*By* JOHN A. STEVENSON.]

INTRODUCTION.

The work of the year in plant pathology and botany has been carried forward along all lines indicated in the previous report, with such modifications as the increased prevalence of some diseases has demanded. Especial attention has been given to the mottling or new disease of cane, and to citrus scab. It has been possible to push investigation in both the laboratory and field, and much information has been obtained along the various lines. The erection of a plant house and the grant of additional assistance make the prospect for the coming year even more satisfactory.

WORK OF THE YEAR.

As in former years much time has been given to field studies in citrus groves, pineapple plantations, and cane fields; and the usual amount of material for laboratory study has been collected, observations and notes made, and such information as was available on various plant diseases given out. An experiment in the application of sulphur in the form of dust, aiming at control of the citrus scab, was carried out at the proper season and observations were made of spraying operations conducted in other groves for the same purpose. Foot-rot, blossom end rot of oranges, and other minor diseases of citrus have received some attention.

The cane disease situation has been especially pressing and has been the basis of a number of extended field trips. In addition, experiments on field plots, and with a large number of pot cultures, as well as laboratory studies have been conducted with this problem. Certain minor cane diseases have received such attention as their importance warranted, and the manuscript of the paper on cane fungi and diseases was put in final shape for early publication. This latter is a joint paper by the former pathologist and the writer, embodying the results of seven years' work on cane diseases, and is planned to fill an entire number of the *Journal of Agriculture*.

The addition of Mr. R. C. Rose to the Staff as assistant patholo-

gist in September has made possible the attacking of our various problems more intensively. He has given especial attention, as is noted hereafter, to vegetable diseases, and in addition has had charge of the laboratory work, involving the preparation of media, isolations from diseased material, as well as most of the inoculations that have been made.

The pathologist spent a week in New York City in October, investigating the rots of citrus fruits as they appeared upon the arrival of the fruit at that port. In the intervals between the arrival of fruit ships, the time was spent at the New York Botanical Garden in studies of Porto Rican fungi and flowering plants. The most complete collection of these is found in the herbarium of that institution. Working with Dr. F. J. Seaver, a start was made in the preparation of a check list of Porto Rican fungi.

PUBLICATIONS.

The policy of preparing press notices and field reports has been continued. A list is herewith appended of those issued in the period under discussion. All have been published in the local (Spanish) newspapers.

"Shipping Rot of Citrus." November 17.
"A New Blossom End Rot of Citrus. December 13.
"Black Rot of Cane Seed." December 13.
"Notes on Citrus Scab." December 26.
"Rind Disease of Sugar Cane." January 12.
"A Disease of Gandules." April 9.
"The Need of a Plant Quarantine." April 10.
"The Plant Quarantine Service of Porto Rico." April 12.
"A new Cane Disease (*Diplodia*)." April 15.
"Lightning Injury to Sugar Cane." April 17.
"The Disease of Bananas and Plantains." May 1.
"Wood Rot of Citrus." May 29.
"Root-Knot and Its Control." June 5.
"The Nature of Fungus Diseases of Plants." June 5.
"Sobre Enfermedades de la Caña." June 13.
"The New Disease of Cane." June 15.

The last two are also being published as circulars 10 and 11, respectively, of this Station.

Further publications of the department have been:

"Report of the Pathologist for 1915–16." In the Fifth Annual Report of the Board of Commissioners of Agriculture, pages 35–74.

"The History and Cause of the Rind Disease of Cane." By John R. Johnston, former pathologist. In vol. one, number one, of the Journal of Agriculture. This paper had been at hand awaiting publication for some time.

"Diseases of Field and Garden Crops." In number two of Journal of Agriculture, pp. 97–117.

"La Enfermedad Nueva de la Caña." In numbers 24 and 25, volume two, of *La Revista Azucarera.*

PLANT DISEASE SURVEY.

It has always been the aim of this department since its inception to carry on, in so far as facilities permitted, a plant-disease survey, the information to be obtained being of value not only because of its scientific interest, but also because of the necessity of having such data at hand for the proper carrying out of the plant-quarantine work. When it appears that a given plant disease does not apparently occur here, a quarantine can be placed against its host. This work has been greatly aided during the year just past by the appointment of the pathologist as Collaborator of the United States Department of Agriculture, Plant Disease Survey. The aid received from this source makes possible the gathering of information on plant diseases with greater facility.

HERBARIUM.

As heretofore, extensive collections of flowering plants and fungi have been made, carrying out the project of obtaining a collection of Porto Rican plants. Many of these have been determined and inserted in the herbarium, although time has not permitted the working over of a large number of the fungus collections. Lack of space has now added to the difficulties of this work. In addition to our own collections, a large number of determined specimens have been received in exchange from other collectors of Porto Rican plants, and from correspondents in the States. As in previous years, we are indebted to Dr. Britton and members of the staff of the New York Botanical Garden and to other mycological specialists for aid in the matter of determinations.

A summary of additions to the herbarium during the year follows (not including collections as yet undetermined):

FUNGI:	
Station collections	746
Exchange specimens, Porto Rican	368
Exchange specimens, not Porto Rican	217
FLOWERING PLANTS AND MOSSES:	
Station collections	432
Specimens received from the Natural History Survey of Porto Rico	916
MOSSES:	
From the New York Botanical Garden	8
Total specimens	2,681

EDITORIAL.

In addition to the botanical activities of the department, the pathologist has edited the new scientific publication of the Experiment Station. This was first designated as the *Journal of the Board of Commissioners of Agriculture*, but the passage of the new Organic Act for Porto Rico and the creation of a Department of Agriculture necessitated a change in the title to the *Journal of the Department of Agriculture of Porto Rico*. Two numbers have been issued to date and a third is in press. Four numbers will constitute a volume, and it is planned to publish quarterly, so that there will be one volume per year. The *Journal* is planned as a medium of publication of the technical papers prepared by members of the staff. It will serve as a means of exchange for other agricultural publications, and so aid in the building up of the library. The present scheme of publication calls for the preparation of a popular account of each article published in the *Journal*, to be issued either as a circular or a press notice.

Some time has also been given to the editing and preparing for the press the fifth annual report of the Board of Commissioners of Agriculture and the other publications of the Station. Supervision of the library has been maintained as in previous years.

THE "MOTTLING" DISEASE OF CANE.

INTRODUCTION.

The cane disease situation in the western portion of the Island has shown no improvement, but on the contrary the epidemic continues to spread and increase in severity. Further studies and observations carried on since the writing of last year's report (12)[1] have led to a change of opinion as to the nature and seriousness of the trouble. Certain views there expressed have been modified, and a considerable amount of information on the various points involved has been secured. At that time it was considered a very severe manifestation of what is commonly known as "root disease," for want of a more comprehensive term. This latter trouble is of more or less common occurrence in all cane-growng countries, Porto Rico in particular, and is generally attributed to long-continued cropping without adequate cultivation, resulting in a "running out" of the fields. The writer now inclines to the view that while there are large areas suffering from this trouble, the mottling disease is to be considered distinct, at least until it can be very definitely

[1] Figures in parenthesis refer to literature cited on p. 76.

proven that the two are but manifestations due to the same fundamental causes. The many points that have been considered in the field and laboratory are discussed in detail in the body of this report.

Whatever the cause or nature of the disease, whether it is parasitic or non-parasitic, the widespread feeling of alarm over the future of the sugar industry of the Island is completely justified by the course of events to date.

DISTRIBUTION.

In studying the disease in the season of 1915–16 the infected area, roughly speaking, was found to extend from a point east and south of Arecibo to Aguadilla, and from the foothills well back into the highlands. It was, however, present to a limited extent in other adjoining districts as the more extensive reports and observations of this year have revealed. The territory between Arecibo and Aguadilla, a rolling stretch of country which suffers much from drouth, has been the most severely infected. As far as it has been possible to ascertain, the trouble originated in this area, apparently in the neighborhood of Isabela, although the first complaint came from the cane growers in the Arecibo valley, and most of the preliminary studies were made in this vicinity.

At the present time the area has become greatly extended, including the territory from a point just west of Bayamón to the Añasco valley, or nearly to Mayagüez. It has been noted that the trouble has been largely confined to the upper reaches of the river valleys, to small enclosed inland valleys, and particularly to fields among the foothills. The broad stretches of the coastal plain, but little above sea level, are still free, or comparatively free, of disease. Near Arecibo many of the lowland fields show on the average one per cent of mottled stools, but farther east, in the lowlands of the Plazuela Sugar Company, it was impossible to find a single diseased stool, although mottling commenced the instant the foothill formation began. This state of affairs was hardly to be expected, if the cause be parasitic, since these lowland fields are planted to susceptible varieties and form great continuous areas, often extending for miles in unbroken stretches.

In its eastward course the disease has apparently jumped from valley to valley, or has appeared spontaneously at many points some distance back from the ocean, rather than working along through the continuous coastal fields and then up each successive valley. It has almost universally evinced a marked preference for upland fields,

in spite of the fact that they do not form the continuous areas so characteristic of the lowland country. Not only are these fields themselves broken up by the numerous small hills, but the many valleys, large and small, are separated by extensive ridges and chains of hills.

Whether or not the trouble will continue to spread at its present rapid rate is entirely problematical, but seems altogether certain, there being no present signs of a lessening in amount of infection present, or in the rate of spread to new areas. Until the field survey now under way is completed it will not be possible to give the exact distribution of the disease, or to state accurately how long it has been present. As far as known now it has been present with certainty three years, and possibly longer, since fields were seen two years ago which were even then in an advanced stage.

AMOUNT AND NATURE OF THE LOSSES INCURRED.

It is extremely difficult to give any definite figures as to the losses sustained to date by the growers because of the great variation in amount and severity of infection from field to field. The monetary loss, however, has most certainly reached a total of several hundred thousand dollars, if not a half million. This is distributed through the sugar production of at least six centrals and a very large number of *colonos* (growers who sell to the various mills), and covers a period of three years. In the coming crop the production of several other mills will be affected and a corresponding number of *colonos*. A study of the statistics of sugar manufactured during the last three seasons does not afford a satisfactory basis for estimating the loss, since the high prices prevailing have caused a great increase in the total area planted which has tended to maintain the total yield at a balance with previous years. It is a fact, however, that in spite of the increased areas planted the production of all mills affected has fallen off, and in some cases to a considerable extent. No certain estimate is possible until the field survey is completed.

In the region between Arecibo and Aguadilla, where the trouble is at its worst, innumerable fields have been already abandoned to cane culture, particularly in the neighborhood of Quebradillas and Isabela, and many others will fail this year. The planters there have practically been forced out of the cane business, and have turned to other crops. Even in the Arecibo valley considerable areas have been given over to pasture, and a number of *haciendas* are about through with cane growing. If there be added to the

fields completely abandoned those in which there is infection to a varying amount present (four thousand acres of this nature were gone over in one valley alone), it is readily apparent that the above estimate of the monetary loss is only too low. All who have had occasion to give the matter attention will agree to this statement.

In the first stages of infection it is not yet apparent that there is any reduction in yield, or amount of sugar in the juice. As the disease progresses, however, and during the second year of its presence as a general rule, there is a very marked falling off in the yield, which may vary anywhere from ten to a hundred per cent. From this stage on there is also an accompanying decrease in the amount of juice in the cane. The final stage in which no merchantable cane is produced and the field is abandoned may occur the second year, but more commonly during the third year, or on the second ratoon. Hundreds of acres have been seen in this latter stage and thousands more are fast approaching it.

In the severely diseased stalks of this latter stage (those showing cankering and splitting), there is not only the reduction in size and the dry, pithy condition due to a lack of juice, but what juice is present is highly objectionable from the viewpoint of the mill. Chemical tests carried out at several Centrals show a very high and objectionable glucose ratio with correspondingly low sucrose and poor purity. Moreover the juice behaves very badly during the process of manufacture, and is especially difficult to clarify in some mills. The fiber and other foreign matter refuses to coagulate and settle out, remaining on top or on the sides of the container, so that it is often necessary to put the larger part of the juice through the filter presses. Under all circumstances special care is necessary in handling it. Because of the unsatisfactory nature of the juice the Centrals refuse to receive any cane which shows signs of the disease. As will be noted later, this would eliminate only cane in advanced stages since there are no external changes in the stalks themselves until the disease has been established for some time. It has not been possible to make exact chemical studies of mottled or cankered canes up to this time, but a complete investigation of this nature is now under way.

NAME OF THE DISEASE.

Various names have been used for this malady. It is universally known among the planters as *La enfermedad*—"the disease"—all other cane diseases of their experience sinking into insignificance in comparison with it. The writer has referred to it at various times

as "the new disease," "the mottling disease," and "cane-canker," but now prefers the use of the term "mottling," or "cane-mottling." As far as known no distinctive colloquial expression has been given to it other than that of "*La enfermedad.*" Cane-canker is not considered suitable, since the canker stage of the disease is not always present. Chlorosis, which might be used, and in fact has been to a limited extent, is pre-empted by a very different type of non-parasitic disease occurring on the South Coast. A search of available literature having failed to connect the present outbreak with any certainty with other described cane diseases, non-parasitic or otherwise, the term cane-mottling or the mottling disease of cane is proposed for it.

SYMPTOMS AND CHARACTERISTICS.

The one marked and constant symptom of this disease, and the one by which it is easily recognized by anyone who has occasion to visit infected fields, is the peculiar mottling of the leaves. It is readily distinguishable from any spotting or striping or other abnormal appearance of cane leaves known to the writer. A search of the available literature has not revealed any disease or phenomenon to which similar symptoms have been assigned. No trouble has ever been had in definitely ascertaining whether or not the disease is present except in a very few cases, where in new areas or new fields a part of a leaf or a few leaves only were found abnormal. A detailed comparison of the symptoms of mottling and other diseases, with which it might be confused, is given further on.

In fully expanded mottled leaves of the type commonly found, the backgrounds are green to yellow-green, depending upon the severity of the case. Two rather distinct types of discoloration have been noted, but always grading into each other, so that it is not considered that they are other than phases of the same phenomenon. Of these one is more common in early stages or light cases, and has been especially noted in the unfolding leaves at the top of a stalk, sometimes changing to the second after a time. In this type the background or larger portion of the leaf blade is a light, abnormal, yellow-green and scattered about in it are areas of apparently normal color, "green islands," as it were. These spots are for the most part linear, but will vary from mere points to irregular blotches several centimeters long by a centimeter wide, always with a decided tendency to greater length than breadth. This phase is much more apt to be confused with certain other phenomena than the second, especially where the disease is making its first appearance in a new area.

The most usual phase of this disease seen, (the one occurring over thousands of acres and in all varieties,) is that in which the leaves are marked with numerous very light yellow-green to nearly white spots and short stripes. The background will vary in color from a normal green in plants but recently attacked to a yellow-green in more severe cases. The markings which produce the mottled effect are always much lighter in color, giving a very decided contrast. They are irregular in shape varying from almost invisible points to irregular spots two centimeters in their greatest dimension. For the most part they are linear, coalescing irregularly, and with indefinite margins. They will at times constitute fifty to sixty per cent or even more of the total leaf area.

The mid-rib remains to all external appearances normal. The leaf sheaths present no abnormal signs, except a faint mottling in early stages of growth.

Mottled leaves do not die and fall away from the stalk any sooner than do normal ones, nor on the other hand is there any tendency to remain past the usual period of shedding. Varietal characteristics hold in this particular, irrespective of the presence or absence of mottling. There is no difference in the size of the leaves until the general stunting of the stools sets in in advance stages.

As a general rule the leaves are uniformly mottled, but in beginning cases examples are not uncommon in which a portion of a leaf only is affected. Such instances have been found where a stalk previously apparently normal commences to show mottling. The lower leaves, anywhere from two to a dozen in number, will be to every appearance normal, then there will occur a leaf showing mottling for a few inches only at the base of the blade, which in turn will be succeeded by several others above affected from a half to two-thirds their length. All above these transitional leaves will be completely mottled. Occasionally one side of a leaf may be affected farther out than the other. The reverse condition of normal-appearing leaves above mottled ones has never been observed. Through the season there may be in this manner a gradual increase in the number of stalks infected or at least in the number showing visible signs.

The disease, or phenomenon as it might more properly be designated, follows what is approximately a three-year course. In the first year of its presence isolated stools only will show discoloration, scattered irregularly over the field and often composing less than one per cent of the total. One to five per cent infected is the common condition found in what is considered the first stage. At this

time the only symptoms will be the mottling of the leaves above described. Often the first phase only will be present, or where the second also occurs the backgrounds will still be dark-green. In a given stool the number of stalks showing mottling may vary from one to all, two or three, however, being quite a common number. This in many cases merely means that the shoots from one seed-piece only are infected (a number of seed pieces, usually four, are planted in each hole and the shoots from these form the stool). It is easy enough, however, to find shoots from a single seed piece only part of which are mottled. At this point in the progress of the disease since no other symptoms than the mottling will be found externally or internally, it is impossible after the leaves are removed to distinguish normal from abnormal cane. The internodes are sometimes somewhat shrunken, but the only sure test is to plant portions of suspected stalks and observe the leaves of the new shoots.

In the second year at the usual rate of procedure a very much larger percentage of infection is present. As far as it has been possible to ascertain, this includes all stools which showed mottling the year before, as well as a varying number of those that had been, when the first crop was cut, apparently normal. At this stage, in addition to the mottling there may be a dwarfing of the stools and the canker stage may be present, depending somewhat upon the variety and possibly other conditions. The dwarfing may be sufficient to cause a loss in yield of from ten to sixty per cent. There is quite a decided shrinking of the internodes whether the stools be stunted or not.

The crop in the third year (second ratoon) is practically a total loss at the usual rate of progress. This is due to the combined effect of dwarfed stools producing very short lengths of cane and the dry, pithy nature of the stalks themselves, due to cankers, cracks, and lack of juice.

There have, of course, been considerable variations from this three-year sequence, depending upon varieties and other circumstances not yet understood, but it holds to a very large extent.

To return to the symptoms:

A second very marked sign is what has commonly been referred to as the canker stage. This occurs more severely on certain varieties than on others, and similarly appears on certain ones before it does on others in point of time. The soft white canes, the Otaheite and bamboo, for instance, are peculiarly subject to it, fields of these varieties often entering this stage in the second year. The Rayada and other hardier canes show less of this phase of the phe-

nomenon as a rule, but fields do occur in abundance where these canes are seriously cankered and rendered absolutely worthless.

The cankering is plainly an advanced symptom, since a stool may show mottling through two seasons before it appears, and in one variety (Sarangola) only a very little has been noted as yet. As with the mottling, two possibly distinct types have been noted, grading into each other, however, to a considerable extent.

The first of these can hardly be designated by the term canker, except as all lesions or abnormalities of the stalks are grouped under this term. It consists of gray, very irregular patches on the internodes, which often coalesce to encircle and practically cover the entire surface. They do not pass from one internode to another. These areas are superficial, including only the outermost layers of cells, or practically the epidermis only. It appears probable that they are merely a result of sunburn, since by the time they appear the stools no longer have a sufficient spread of foliage to shade the stalks, as under normal circumstances. Exactly similar phenomena have been observed in other parts of the Island on stalks at the edges of fields or in positions exposed to the direct light. Shrinkage of the internodes usually accompanies this stage. This particular phase is not of sufficient importance to warrant further consideration.

The second and important type of stem lesions originates and can be found on the internodes by the time the leaf sheaths have become somewhat loosened, but before they have fallen away. There is a considerable period, varying with the varieties in the duration of the life of each leaf during which its leaf sheath adheres but loosely to the stalk, permitting water and fungus spores to gain access to the underlying internodes. At this period, then, the lesions are first noted, as somewhat shrunken areas with a water-soaked appearance, soon becoming medium brown in color, and oval to linear, often irregular in shape. With the falling of the leaf they pass through various shades of brown, and finally to an ashen or dull gray color, being still sunken, linear, and often coalescing to form large irregular areas more or less completely covering the entire internode. On the other hand, they may be limited to a few only on each internode. The margins of the lesions are quite distinct. They do not pass from one internode to another, the nodal regions forming a sharp line of demarcation.

Penetration of the tissues is never very deep, hardly more than from one to two millimeters at best, and is often limited to a few layers of cells only. The affected tissues are red, but not different in shade or other characteristic from similar effects produced

by other causes. There are no other internal symptoms except as noted below.

Cracking very often accompanies the cankering, and along these openings the same reddening of the tissues occurs, but it is of the same nature and extent as occurs in splitting of normal cane. Cracking is by no means an uncommon phenomenon of such canes, some varieties, and especially large stalks, being very subject to it. For this reason no special significance is attached to it as it occurs in connection with the cankers, other than considering it a result of the drying of the stalks, quite to be expected.

In addition to the stunting or dwarfing of the stools, there is a shrinking of the internodes of the individual stalks. This is especially pronounced in what might be termed third-phase cases, or those in the last stages of the disease. Such stalks are almost completely lacking in juice, the limited amount of pith tissues formed being of a rubbery consistency. Where the trouble is not so far advanced the lesions may be present to a greater or less extent without an appreciable shrinkage of the internodes, or visible effect on the amount or quality of the juice. It is juice from this class of cane, however, which has been the cause of so much trouble in the factory. Third-phase canes never reach the Centrals, the growers abandoning such fields to pasture, knowing that the cane is unsalable.

One peculiar circumstance that has been often noted in fields in approximately the second phase of the disease has been the finding of stalks showing only part of the internodes cankered. For instance, the lower five or six would be apparently normal and all above cankered and shrunken, or the lower internodes normal with five or six above cankered and the balance above again apparently healthy. As an extreme case may be noted a stalk of Rayada found above Arecibo, the condition of the internodes of which, proceeding from bottom to top, was recorded as follows: Four normal, five shrunken and cankered, four normal, five shrunken and cankered, top joints to all appearances normal. This sequence is undoubtedly due to an alternation of wet and dry periods.

In every case examined cane showing cankers, even if of one internode only, has also been found to have all the leaves mottled. On the contrary it has been very common to observe field after field showing mottled leaves in abundance but with no stalk cankers present.

There have been reports of apparent recovery from the mot-

tling condition, but it has not been possible to investigate any such cases and they are considered very doubtful at best.

A rotting of the bud is never a sign of this disease, and such limited cases as do occur can always be attributed to *Diatraea* or other agencies independent of mottling.

Nothing abnormal has been found in so far as the roots are concerned. As would be expected with cane growing under the conditions which have prevailed in the infected territory, there can always be found great numbers of dead roots, but no more than in normal cane growing in the same region. In the planting tests at this Station roots were produced in equal abundance by both types and no differences were discernible. The presence of one or more root fungi, of course, often complicated diagnosis, a point discussed under another head.

It is not believed that there is any noticable loss in germinating power of seed from affected stalks except those in advanced stages. Nothing of this nature has been noted in the planting tests nor has it been reported in the field, although of course very little seed visibly infected has been planted, at least in the last year or two.

The symptoms of the mottling disease in brief may be said to be a mottling of the leaves, with no other observable change in the plant at first, followed, generally in the first or second ratoons, by a dwarfing of the plant, the presence of cankers or lesions on the stalks, and a decrease in the amount of juice.

VARIETIES ATTACKED.

Not one variety has been found to date which has been resistent or even practically so to the extent that its use would avoid the greater portion of the loss. The two principle types grown throughout what is now the infected region are the Otaheite (*caña blanca*) and the striped or Rayada. In addition to these two there are considerable areas of other varieties, *cavengerie* or *caña de vino*, penang, Sarangola, and bamboo. For a number of years the Experiment Station has been sending to this part of the Island, as to all other sections, a considerable number of new foreign varieties, mostly seedlings, for trial. Porto Rican seedlings produced at the Station have not been available until this time.

There has been a considerable variation with the different varieties as to the amount of disease present. The Otaheite and bamboo have been quite uniformly severely attacked and their elimination, or at least of the strains growing in the western half of Porto

Rico, seems certain. The report of last year gave some further information as to the status of the Otaheite or *blanca*. The common striped cane or Rayada has in some parts of the district shown a considerable amount of resistance, but is now quite generally succumbing and seems to be no more satisfactory than the white (Otaheite). The *caña de vino* (Cavengerie) has likewise followed a similar course. The Sarangola, a dark-red cane, still retains considerable resistance, but is not grown widely and doubtless will not be, since it is undesirable from the mill standpoint. Moreover, it has been found infected to an extent that makes it probable that any attempt to cultivate it extensively would only bring about its complete downfall.

Of the various other canes of recent or comparatively recent introduction, not one has proven to be completely free of the disease, although some still show a fairly high degree of resistance. Yellow Caledonia, B–208, B–3412, B–109, B–376, B–347, B–3405, and Crystallina, wherever seen by the writer, particularly at Camuy, near Arecibo, and at Utuado, have been absolutely unsatisfactory. At Utuado plant cane of a small piece of B–1809 was in fair condition. D–117 and D–109 have been reported from Coloso as the most resistant of the various types under trial at that place. B–208 is giving fair yields at some points, but as noted above is a failure in others.

A great deal of further work is necessary in introducing for trial all other possible varieties in the hopes of finding one or more that will prove satisfactory. It is a well known fact, borne out by the above notes that a variety, a failure in one locality, may be quite successful in another, suggesting that not one but several varieties will be needed to solve the difficulty and that each district will present a separate problem.

CAUSES.

Continued efforts have been made to ascertain definitely the cause, but it still remains obscure. A considerable number of possible factors have been suggested and studied, but nothing has as yet been found which experimentally could reproduce the disease. During the first year, as was stated in the first report on the situation (12[1]) the opinion was held that it was merely the result of too extensive planting without seed selection or proper cultivation practices, acting in combination with very unfavorable weather conditions—a drought followed by an excessive wet period—resulting in what is commonly referred to in the literature of cane diseases as an epidemic of root

[1] Figures in parenthesis refer to literature cited on p. 76.

disease. As a result, however, of continued field observations, and laboratory and plant-house tests, it has become only too apparent that the problem in hand is something more than the ordinary "root disease" or deterioration proposition.

Tests of the juice.

Among the first tests made were those with the object of ascertaining as to whether or not the juice of mottled canes would prove to be infectious. Three such sets of experiments[1] were made during the year. In all of these a stalk, the leaves of which were distinctly mottled, was ground up, the juice expressed and used immediately for inoculation into normal cane growing on the Station grounds. In the first, five stalks in each of five rows of Yellow Caledonia were inoculated, using a hypodermic needle. In the second set the juice was similarly obtained and leaves and stalks of several varieties were inoculated as follows:

Otaheite, Stool No. 1: 5 leaves, 3 stalks.
Otaheite, Stool No. 2: 4 leaves, 2 stalks.
Otaheite, Stool No. 3: 3 leaves, 4 stalks.
Yellow Caledonia, Stool No. 1: 3 stalks.
Yellow Caledonia, Stool No. 2: Juice poured over stumps. (Stalks cut off at ground level.)
Rayada, Stool No. 1: Juice poured behind the leaf-sheaths of 3 stalks.
Rayada, Stool No. 2: 6 stalks.
D–117, Stool No. 1: Juice poured over the roots.

The third test was made after the same fashion, using a fountain-pen filler to place the juice in holes made in the stalks by a sterile instrument. All the stalks in two stools of B–376 and three of Otaheite were inoculated. Two stools of B–376 adjoining those inoculated were showing mottling at the time.

The results of these inoculations have been uniformly negative, not a single stool nor stalk in any of the stools showing the slightest signs of mottling, nor have any of the checks. That under some conditions at least the cane used would have been susceptible if a parasite had been present, is apparent in that a number of stalks of two stools of B–376 have been mottled throughout the season, and all the other varieties used have been noted as susceptible.

Examination of the leaves.

Equally negative results have been obtained with studies of mottled leaves. Sections examined show no differences from those of

[1] All inoculations were made by Mr. R. C. Rose.

normal leaves except in the absence or deficiency of chlorophyll in the chlorotic spots. A number of attempts have been made to plate out some organism which would prove infectious, but no traces of any such form, bacterial or fungal, have been found. As would be expected, these cultures have yielded from time to time, *Leptosphaeria sacchari*, *Helminthosporium sacchari*, *Valsa sp.*, *Trichoderma lignorum*, *Fusarium sp.*, *Colletotrichum sp.*, and occasionally other fungi. Not one has appeared with any uniformity. For the most part further trials with these fungi have not been considered necessary since not only have they not appeared uniformly, but the nature of their attacks on sugar-cane leaves, where they are capable of such action, is known. The first two mentioned cause very characteristic spots, which are found abundantly in all parts of the Island and on practically all varieties of cane.

Particular attention has been given on field trips to the relation of the various leaf spots to mottling. It has been found that there is no direct relation; that is to say, mottled cane shows no more or no less of these spots than does normal cane of the same varieties. Leaf spots are very prevalent throughout the entire western part of the Island, and it is quite certain that they are independent of the new disease except in so far as they destroy leaf surface and so help to weaken the plants. The various leaf diseases are treated more fully in another recent publication (5).

Examination of the stalks.

The search for a parasite in the stalks has been equally fruitless. The absence of any distinctive internal symptoms in the form of rot, gumming, etc., has made it very doubtful from the first whether a parasite would be present. A special search was, of course, made for rind disease (*Melanconium*), red rot (*Colletotrichum*), gumming (*Bacterium vascularum*), or other parasitic stalk diseases. Suffice it to say that while isolated cases have been found of the common stalk diseases of Porto Rico (gumming does not occur here), they have not been present to even an extent where appreciable damage was being caused, nor was there any connection with the mottling. A comparison of these and other diseases with mottling is taken up in detail later.

The common, easily recognized fungi having been eliminated, attention was turned in the laboratory and in the pot cultures to an attempt to find a more obscure parasite or other cause. Tissue cultures and damp-chamber tests have been made from time to time, both of cankered stalks and of stalks which were normal except for

leaf mottling. Cultures of representative cankers made November 1 gave *Valsa sp.* and *Trichoderma lignorum.* On December 11, tissue cultures of stalks of B–208 and Yellow Caledonia proved sterile. In sterile moist chambers, sections of the stalks produced a growth of *Trichoderma,* and in one instance of *Schizophyllum.* Seven lots of cankered cane were tested in damp chambers under sterile conditions, beginning December 26. Of these, two remained sterile, one produced *Trichoderma,* and four were overgrown with *Aspergillus niger,* but were otherwise sterile.

Similar tests were made in January of portions of mottle-leafed and cankered stalks brought in for planting tests with the following results:

No. 1.—Otaheite, stalk not cankered. *Aspergillus niger* and *A. flavus.*

No. 2.—Rayada, stalk cankered. *Colletotrichum falcatum, Trichoderma, Aspergillus.*

No. 3.—Rayada, mottled only. *Trichoderma.*

No. 4.—Sarangola, normal and cankered stalks. *Aspergillus* on both.

No. 5.—Rayada, stalk cankered. *Trichoderma.*

No. 6.—B–3412, mottled only. *Aspergillus, Trichoderma.*

No. 7.—Otaheite, stalk cankered. *Colletotrichum,* later overgrown by *Trichoderma* and *Aspergillus.*

No. 8.—Cristallina, mottled only. *Aspergillus, Trichoderma.*

A further series of tissue cultures was made, all precautions to obtain sterile conditions being taken. Short sections of stalks were immersed in mercuric bichloride (500–1) for several minutes, rinsed in sterile distilled water, and in the culture chamber, fragments removed with sterile instruments for planting in beef-agar plates. The majority remained sterile until completely dried out, *Aspergillus niger* appearing on some, but quite plainly as a contamination.

An additional cultural test using both mottled leaves and portions of the stalk (April) gave no results.

To still further examine into any possible relation of the more commonly occurring of the various fungi, several inoculation experiments were carried out. In the first of these *Colletotrichum falcatum* was used as the inoculating agent and D–117 as the host. Ten stalks were punctured with a hypodermic needle and material from a pure culture (isolated from No. 7, above) inserted. Ten other stalks were similarly prepared, except that sterile water was used in place of the fungus. From time to time inoculated stalks were cut and examined. At no time was there any evidence of even the beginning of red rot. The only abnormal sign was the red discoloration around the puncture, such as occurs around any wound.

The checks remained without change. At the same time midribs of ten leaves of adjoining stools were inoculated, using the hypodermic needle and the same inoculum. Typical cases of red striping resulted, while all but one of ten checks showed no change. Twenty-nine additional inoculations of leaves made in the same manner gave the same result. Neither series gave any evidences of mottling at any time.

A series of puncture inoculations of midribs was made, using pure cultures of *Melanconium sacchari, Thielaviopsis paradoxa, Cytospora sacchari, Sclerotium Rolfsii,* and *Trichoderma lignorum.* With the exception of the latter all produced red striping, varying somewhat in the shade of red, but otherwise characteristic of this disease. There were no other evidences of disease. A similar experiment, using *Melanconium,* several different strains of *Colletotrichum, Cercospora vaginae, Cytospora, Thielaviopsis,* and *Sclerotium,* gave the same results. No mottling has appeared in these canes, although from four to nine months have elapsed since the inoculations were made.

Field experiments.

As a consequence of previous experience, field observations on the disease for over two years, and the above experiments, it appeared quite certain that none of the above fungi were concerned, with the possible exception of *Colletotrichum falcatum,* which had been obtained to some extent in tissue cultures, and had been observed rotting seed pieces in the fields where mottling was present.

A field experiment with this fungus was therefore planned at the Station. One hundred and fifty selected seed (cuttings) of each of eight varieties were prepared by retrimming the ends and soaking them in Bordeaux mixture. Any showing signs of borer (*Diatraea*) or internal discolorations were rejected. A hole was made about midway of each piece with a sterile nail after the surface had been cleaned with alcohol. Fifty seed of each variety were set aside as checks after the holes had been sealed with grafting wax. Seventy-five were inoculated with *Colletotrichum falcatum,* using a pure culture obtained from a cankered cane stalk and twenty-five with *Valsa sp.* from the same source, the openings being sealed with grafting wax. All were planted under ordinary field conditions, each variety in a separate row, and the rows parallel.

Weather conditions proved rather unfavorable and the death of many seed pieces was attributed to this cause. Of those inoculated with *Colletotrichum,* from ten to thirty-five per cent died and showed

all evidences, both in the internal red rot and the surface fruiting patches, that this fungus was responsible for the failure to germinate. Further details of this experiment, while interesting, have no further connection with the matter in hand, since neither of the fungi used produced the slightest sign of mottling. The varieties used were Crystallina, Rayada, Otaheite, B–208, Yellow Caledonia, Caña de Vino, B–3412 and D–117, the principal types observed in the infected district. It might be added that a great number of fungi were found on the dead seed pieces, not only on those that did not germinate but on those that produced normal shoots as well. These were about the same as have been mentioned on preceding pages, the common saprophytes.

A similar experiment but on a smaller scale and using only two varieties was commenced in February. In this case, in addition to the previous precautions, the ends of the seed pieces were tarred. Each of the following fungi, *Colletotrichum falcatum, Trichoderma lignorum, Fusarium sp., Sclerotium Rolfsii, Melanconium sacchari,* and *Cytospora sacchari* were used to inoculate ten seed pieces. Twenty checks were also prepared. Most of these cultures had been obtained from cankered cane. While a considerable number of seed pieces in each case failed to germinate, the cause was readily attributable to the fungus employed or to other unfavorable conditions. No evidences of mottling have appeared to date (after nearly seven months).

But one other experiment was tried along this line. Four varieties, Rayada, Yellow Caledonia, Otaheite, and D–117, were employed, untreated seed pieces being planted in steam-sterilized soil in 5-gallon cans. A flask culture of *Colletotrichum*, the same strain as was used in the other tests, was diluted with sterile water, shaken, and the contents poured over the cut ends of the seed pieces. The results were negative.

Cause of the cankers.

Cultures and inoculations have failed so far to give any exact clue to the cause of the cankers, and the following explanation is, it must be admitted, largely theoretical as yet. In part there is little doubt but that sun burn will explain the blotches, due to failure of the cane to obtain sufficient size and spread of foliage to protect the stalks. Where the lesions are more of the nature of true cankers, as explained under symptoms, it is supposed that they are one of the manifestations of weak cane, with more or less fungus present as a secondary agent. As has been already stated, cankers

occur only in the advanced stages of the disease and in many instances on parts of the stalks only. It appears to be a fact in this latter case that the internodes showing the cankers are those that were produced during a dry period. Hence it has been concluded that, together with the shrinking and drying of the internodes, they are a result of the lack of sufficient water in the soil or in the inability of the weak plant to absorb it.

There are, of course, always present plenty of fungus spores, washed down behind loosened leaf sheaths, and they may well aid in increasing the cankers in size and numbers. If, however, they were concerned to any extent as primary agents there would be found innumerable cases of red rot, rind disease, brown rot, etc., the fungi causing these being omnipresent in all cane fields, and especially apt to attack weak cane. Inoculations in an attempt to produce cankers have failed.

It is rather difficult to handle this point since the cane used will be for the most part either too resistent for infection or in such condition that cankers will be occurring naturally. An attempt is being made to obtain data along this line by using mottled canes in the first or second phase of the disease and controlling the moisture supply.

It has not been possible in field studies to go into the problem of root behavior and it remains to be taken up in the coming year.

Experiments in transmission of the disease.

A number of tests were made to ascertain as to whether or not the disease was carried over in the seed. For this work five-gallon oil cans only were available, which are rather small for growing cane to maturity. However, they served fairly well in lieu of anything better. In all of these plantings the seed pieces were recut prior to planting, soaked fifteen minutes in Bordeaux mixture and planted immediately. Most of the plants suffered severely from *Diatraea* and there was a heavy infestation of the striped weevil (*Diaprepes spengleri*), white grubs (*Phyllophaga spp.*) and other insects. Regulation of the moisture supply gave the most trouble, since the containers dried out very rapidly, and with a press of other duties it was not possible to give personal attention to this detail. It is expected that these adverse factors will be controlled to a greater extent hereafter. Unless otherwise noted, the soil has been a fair quality black loam such as is used in all potting work, flats, etc., at the Station.

The first planting was made on December 9, seed for checks be-

ing taken from fields on the Station grounds. Examinations were made from time to time as to the presence or absence of mottling, and the number of shoots produced. Neither in this experiment nor in any of the others was there any apparent correlation between the disease and the number of shoots produced. Furthermore, the moth-borer killed a number in each can, and in some instances there was also a varying number of buds per seed piece, so that figures as to the number of shoots produced are omitted. The results of the first and last examinations only are given unless intervening dates showed facts of importance.

Table No. I.—Results of First Series of Pot Experiments.

Group	Can No.	Soil	February 8, 1917	July 25, 1917
A.	1	Sterelized (by steam)	Leaves mottled	Leaves mottled.
	2	Untreated	" "	" "
	3	"	" "	" "
	4	"	" "	" "
B.	5	"	" "	" "
	6	Sterilized	" "	" "
	7	Untreated	" "	" "
	8	"	" "	" "
C.	9	Sterilized	" "	Dead.
	10	Untreated	" "	Leaves mottled.
	11	"	Dead	
D.	12	"	Leaves mottled	Leaves mottled.
	13	"	" "	" "
	14	"	" "	Dead.
	15	Sterilized	" "	Leaves mottled.
E.	16	"	Leaves not mottled	Leaves doubtful.?
	17	Untreated	" " "	Leaves not mottled.
	18	"	" " "	" " "
F.	19	Sterilized	" " "	" " "
	20	Untreated	" " "	Leaves mottled.
	21	"	" " "	Leaves not mottled.

A. Yellow Caledonia. Seed obtained from near Arecibo, plant cane, seed for which was obtained from this Station. It had been planted in soil said never before to have been in cane (?), although surrounded by diseased fields. The field showed about thirty per cent of mottling, and later the first ratoons were a total failure. This test was made with uncankered stalks, the leaves of which were mottled.

B. Rayada. From near Arecibo, typically mottled and cankered, nodes shrunken.

C. Yellow Caledonia. Same as A, except that the stalks were lightly cankered, and but little shrunken.

D. Same. Stalks very badly cankered and shrunken.

E. Check. D–117. Seed from Station fields.

F. Check. Yellow Caledonia. From Station fields.

Since all of these tests are of a similar nature discussion will be given for all at one time.

Soil for the second experiment (planted December 13, 1916) was a heavy clay obtained from a field in the Arecibo district, which had been abandoned to cane culture because of the disease. A portion of this was sterilized (cans Nos. 1, 2, 3) by steam (one hour at about sixty pounds pressure), and the remainder untreated. The seed used was the same as that of the planting of December 9.

Table No. II.—Results of Second Series of Pot Experiments.

Can No.	Seed	February 8, 1917	July 25, 1917
1[1]	B.	Leaves mottled	Leaves mottled.
2[1]	D.	" "	" "
3[1]	E. F.	Normal	" " [2]
4	B.	Leaves mottled	" "
5	A.	" "	" "
6	A.	Normal	Normal.
6-a	F.	"	Leaves mottled.
7	F.	"	Normal.
8	D.	Leaves mottled	Leaves mottled.
9	C.	" "	" "
10	E.	Normal	Normal.

[1] Soil sterilized.

[2] Mottling was first noted on two out of six shoots on March 6, this proportion continuing until June 25, by which time all were affected.

On December 23, another set of plantings was made in order to obtain further data on canes which were being examined in the laboratory at this time. Steam-sterilized soil (Station black loam) was used.

1. Caña de vino (Cavengerie), a stalk from Camuy, apparently normal but from a stool, other stalks of which were showing mottling. In the local test all shoots remained normal.

2. B–3412. Stalk of mottled plant cane obtained near Camuy, seed for which had been sent from this Station. Most of the field was showing mottling. All shoots from the piece planted were mottled.

3. Otaheite. From near Camuy, a field 100 per cent infected. All shoots produced were mottled.

4. Cristallina. A diseased stalk from near Camuy, field showing about fifty per cent of mottling. All shoots were mottled.

A fourth and final planting experiment was started January 5th, using the ordinary Station potting soil untreated. The seed was all obtained from various badly diseased fields near Central Alianza.

Table No. III.—Results of Fourth Series of Pot Experiments.

Can No.	Variety	Condition of seed	February 8, 1917	July 25, 1917
1	Caña de vino	Normal	Normal	[1]Leaves mottled
1-a	Caña de vino	Leaves mottled	Leaves mottled	" "
2	Bamboo	Cankered and mottled	" "	" "
2-a	Bamboo	Leaves mottled only	" "	" "
3	Caña de vino	Normal	Normal	Normal
3-a	Otaheite	"	"	"
4	Bamboo	Cankered and mottled	Leaves mottled	Leaves mottled
4-a	Bamboo (Same stool)	Normal	Normal	" "
5	Caña de vino	"	Leaves mottled	" "
6	Caña de vino (Same stool)	Leaves mottled	Normal (?)	Doubtful
6-a	Caña de vino (Same stool)	Mottled and stalks cankered	Leaves mottled	Leaves mottled
7	Yellow Caledonia	Normal	Normal	Normal
7-a	Yellow Caledonia (Same stool)	Mottled and cankered	Leaves mottled	Leaves mottled
8	Rayada	Normal	" "	" "
8-a	Rayada (Same stool)	Mottle-leaved	" "	" "

[1] Changed to diseased condition during May.

These results seem to warrant certain conclusions as to the behavior of diseased canes, although it is recognized that they are by no means conclusive. The entire series is being repeated on a much larger scale in a closed plant house, where most of the insects, the moisture supply, and other conditions can be more nearly kept under control. However, even from the limited tests made it is quite apparent that all cane shoots springing from seed pieces which were from cankered or mottled-leafed stalks will be diseased in spite of soil sterilization and disinfection of the seed. One exception only occurred in our tests, and that one was very doubtfully normal. The disease, whatever its cause, is carried readily in the seed pieces.

Of the various seed pieces taken from apparently normal stalks of stools which were diseased in part, about half produced normal shoots and the remainder mottled. This phase of the experiments is rendered uncertain by the fact that a stool of cane under the planting system usually employed in the western portion of the Island consists of the growth from about four seed pieces, and since it seems apparent that the disease is transmitted through the individual seed pieces, it is undoubtedly a fact that in many instances the planting of one or two diseased seed pieces together with normal ones accounts for the presence of both types of stalks in the same stool. After the first cutting it is difficult to trace the separate plants composing each stool. There have been found, however, examples of normal and mottled shoots arising from the same rhizome. This condition of affairs, then, will account for the results obtained in planting apparently normal stalks.

Although, of course, further work will be done along this line, it is felt that there is sufficient evidence to support the recommen-

dation that no seed be taken from stools mottled or cankered in part, and that the same precaution should apply to fields showing any considerable amount of disease. This point is taken up under control measures.

There have been no instances of recovery noted once mottling appeared. A few such cases have been reported, but it has not been possible to ascertain anything further concerning them.

It will be noted that of the checks, number 20 in experiment one and numbers 3 and 6–a in experiment two became mottled. This occurred some months after planting, and in the absence of any other visible cause is attributed to the drying out and baking of the soil to which the moisture-loving Yellow Caledonia cane was subjected. Although further studies will be made, it is now the opinion of the writer, based on the foregoing experiments and the various field observations, that the disease is not due to any parasitic cause. Other possible causal agencies have been considered, although it has not been possible to deal with them in so exact a manner as with the fungi.

Other possible causes.

Of the considerable number of theories suggested the one which warrants most serious consideration is the relation of the weather to this epidemic, and more particularly the periods of drouth. The records of the United States Weather Bureau have been studied in an endeavor to correlate the rainfall, or perhaps the lack of rainfall, with the inception and spread of the mottling, but this has not been very successful. The greatest difficulty has been in the nature of the rainfall of Porto Rico, which in large part comes in the form of numerous local showers. This means that there is the greatest possible variation in precipitation from locality to locality. For instance, one valley may be suffering from a prolonged drouth while only a few miles away there may be a sufficiency of moisture. Therefore if it is found, for example, that the precipitation for Camuy was at a certain figure for any month, it does not mean that the country directly to the south had the same amount of rain by any manner of means.

Considering the annual precipitation, it is found that Arecibo tends to approach the average for the Island, that Isabela and Camuy fall below, often as much as twenty inches, but that Utuado and the districts east of Arecibo exceed the average. It therefore appears that precipitation records will in general give no clue.

A study of the seasonal distribution of the rainfall is more sug-

gestive of possibilities, and as stated in last year's report (12), in this may lie one of the important factors influencing the disease. A serious drouth in the region from Arecibo west occurred in the first months of 1916 and was preceded by excessive rainfall during the latter part of 1915. A similar drouth occurred during the first part of the present year but was not so serious as that of the preceding year.

In the absence of controlled experiments, heretofore not possible, as to the effect of the moisture supply on the health of the cane only the results of observation and reports of other workers can be given. It is often stated that drouth is injurious to the growth of cane, and is especially provocative of the so-called "root disease" situation. This idea, in connection with the fact that the disease took its start in a dry, unirrigated section of the Island and is still raging there unchecked, and that furthermore the lowland fields with their deeper, less compact soils which are more retentive of water are comparatively free of it, might lead to the conclusion that lack of moisture was an important casual factor.

Against this view may be brought the facts that Utuado and other districts which have not suffered from these severe drouths, at least as far as the weather records show (Utuado had 21.70 inches of rain from January to April, 1916), have also been severely infected, and that although the season of 1917 to date has been normal as to precipitation the disease is apparently unchecked and still spreading.

Many have been inclined to lay the blame on the fertilizer used or on the absence of one or more of the customary ingredients. No evidence whatsoever has been obtained to support this theory, and while some tests will be made it is not believed that there is any direct relation as far as causal considerations are concerned.

The writer has always maintained that a large part of the trouble, whatever else might be involved, was in the nature of the cultivation, or rather in the lack of cultivation, given. This point is quite fully discussed in the previous report, and while, as will be noted, under control even this theory has been severely shaken, yet proper cultivation prevails against so many diseases of cane that it will take considerable more demonstration before the stand taken on this point will be abandoned.

The question of the cause, transmission through the seed pieces being proven and a parasitic theory eliminated, finally comes down to a discussion of the rather obscure phenomenon of degeneration. This term is perhaps to be classed with that used by some plant pa-

thologists to designate the group of diseases due to unknown causes—"physiological diseases"—but it will at least serve to indicate the apparent nature of the disease in question.

Degeneration or atavism is a recognized prenomenon not only in cane varieties but in other crops—potatoes, for example—as well. Prof. Stewart (15) of the Geneva, New York, Experiment Station, reports at length on the degeneration, often appearing very suddenly, of standard varieties of potatoes as marked by leaf-roll, curly-dwarf, mosaic, and other forms. He finds that these diseases are due to some unknown cause, not parasitic, and that they are transmissible through the seed tubers. The descriptions given of the course of the degeneration, manner of appearing, and other points have been repeated almost exactly in the cane situation under consideration.

To quote from his bulletin, "A striking feature of the study was the frequency with which the progeny of plants having normal foliage and high yield suddenly degenerated into worthless dwarfs.

"There is no evidence that any one of the forms of degeneration named is communicable from one plant to another except through the medium of the seed tubers. They are not due to any parasitic organism, neither are unfavorable soil or weather conditions of the current season responsible.

"Neither normal foliage nor high yield is a guaranty of productivity in the progeny of the following season. Degeneration may occur quite suddenly.

"It is unsafe to select seed potatoes from fields containing many degenerate plants. Even the normal plants from such fields are liable to produce worthless progeny."

The degeneration of potatoes has been also dealt with by Orton (10), Wortler (17), Fitch (3), and others. Their work agrees in substance with Prof. Stewart's conclusions.

Substituting the terms cane and seed pieces for potatoes and seed tubers, the above outline applies almost word for word to the mottling disease.

One serious objection entertained at first with regard to considering the new disease a type of degeneration was the fact that it was not confined to the Otaheite and other native canes of long-continued cultivation, but had also attacked all the other varieties sent in for trial. The facts concerning potato degeneration as given by Prof. Stewart quite effectively removed this doubt by showing that the appearance of abnormalities in plants of normal appearance

and yield can be very sudden, apparently uninfluenced by climatic or cultural conditions.

Degeneration in the sense used here has not, it is believed, been correctly applied to cane disease before, except possibly in the case of the Sereh disease of Java. In this instance degeneration was considered by some writers among the many causes suggested, but was apparently never given any very great attention.

There exists a phenomenon long recognized by all workers with sugar cane and often referred to as degeneration, but which is more properly designated as deterioration and so considered distinct from the former. Realizing the great deficiencies in present knowledge of the entire subject of degeneration and related phenomena and more specifically of the mottling disease, it is admitted that this division may not hold, but it will at least serve to make the present situation more clear until such time as a more nearly correct classification is possible.

The chief grounds for so recognizing the mottling disease as a form of degeneration and deterioration as a distinct phenomenon are several. First, the symptoms are quite different in important respects, as may be seen by comparing the accounts given of the two. Second, while they often occur in the same stool of cane they have also been found alone in countless instances. Third, no cause has been found for mottling, but deterioration is undoubtedly due to certain well-known causes. A discussion of deterioration is given hereafter under the succeeding heading.

After having examined various possibilities it is concluded that the new disease or the mottling disease of cane in Porto Rico is due to some unknown cause not parasitic, and that it may be considered as a form of degeneration.

COMPARISON WITH OTHER CANE DISEASES, PAST AND PRESENT.

It has been considered advisable, in order to round out the subject and make it as clear as possible, to present a comparison of the mottling disease with other cane diseases with which it might be confused; as well as a consideration of certain other disease epidemics of the world's history which may serve to throw light on the present trouble.

The epidemic of 1872–80.

There have been several other serious epidemics or epiphytotics of disease in Porto Rico before the present one. The one entailing the greatest loss (estimated at $796,500) occurred between the years

1872–1880, reaching its height about 1876. A commission of three local men was appointed by the Government to study the disease and in 1878 they presented a lengthy report (1). The region infected as given in this publication, included the cane lands around Mayagüez, Aguadilla, Hormigueros, San Germán, Cabo Rojo, and to a limited extent some territory beyond these municipalities, both on the north and south coasts. This was what constituted the fourth department of the Island.

In many respects the observations of the commission corresponded with those noted for the present trouble. The disease spread rapidly, quite irregularly, and was not checked by rivers or hills. The symptoms are described as follows:

"Los fenómenos que presagian el principio de la enfermedad son regularmente cierto tinte amarillento que se nota sobre los cañaverles, el desarrollo tardío y difícil de las cañas, y una vez cosechadas y molidas, la baja en el rendimiento. Al año siguiente en las cañas que nacen al parecer buenas y lozanas, reaparece el tinte amarillento del primer período y continúan así hasta los 4 ó 5 meses, que corresponden al desarrollo de los primeros cañutos.

"Después continúa el color verde amarillento en todas las hojas que acaban por secarse, primero las inferiores y sucesivamente las demás, mientras los cañutos que van saliendo permanecen cortos y delgados; la yema terminal o cogollo se seca a su vez, y por fin, arrugándose primero los cañutos superjores o más débiles y después toda la caña, termina ésta por secarse completamente.

"Cañas enfermas procedentes de cañaverales enfermos, sembradas en terrenos sanos y distantes del foco de la enfermedad han producido cañas sanas, y cañas sanas extraídas de los más excelentes cañaverales, trasplantadas a los que sufren o sufrieron han producido cañas enfermas."

There were no other consistent symptoms. The occasional cases of internal red rot, and rot of the buds were probably due to specific causes. The common cane insects were studied and a decision made that they were not directly concerned. A study was also made of weather conditions with particular reference to drouth, but it was found impossible to make any correlations. All measures such as increased fertilization, use of lime, ashes, and a number of chemical poisons were without effect. The commission after frankly admitting that they had been unable to find a cause advised the immediate extension of planting of several hardy varieties, particularly morada and cristallina, in place of the universally grown white

cane (Otaheite) which had shown no resistance. They also advocated the introduction to the Island of new varieties from other parts of the world.

While in some respects this epidemic resembled the one now at hand, a perusal of the symptoms as compared with those of the latter does not make it seem probable that they are the same. No reference is made to mottling or stem cankers, but to a yellowing of the leaves only, followed by a drying of the bud.

Some years later Don Manuel Fernández Umpierre (2) administrador of Central San Vicente, published in his work on sugar cane an account of the same epidemic and his experience in controlling it. According to his statements, the disease yielded to careful cultivation with particular attention to drainage, even though the very suscepible Otaheite was used. It is quite probable that by the time he took up the problem the disease had about run its course, and even at its height it had hardly extended as far east as San Vicente. Other points, such as origin of the seed used in his experiments, are not sufficiently clear to warrant further discussion of this paper.

In 1895 Don Fernando López Tuero, director of an Experiment Station at Río Piedras (not the present Station) published as part of his work on sugar-cane a lengthy article on what he considered to be the same disease. After investigation of a number of possible factors he decides that white grubs (*Phyllophaga* spp.) are responsible, and proves this theory to his own satisfaction by a series of field observations and planting tests. The present writer inclines to the belief, after a close perusal of López's paper, that he was correct in his surmise that white grubs were responsible for the death of cane over large areas, but that this was a phenomenon entirely distinct from the epidemic of former years. His description at least does not suggest the mottling disease, but is fairly exact for white-grub injury. Still a further point making it improbable that he was working with the epidemic disease of 1872–78 was the fact that he reports his trouble as causing losses in all parts of the Island, including Vieques, whereas the other was confined practically to the Fourth Department.

Other Porto Rican cane-disease epidemics.

This, so far as known, includes all recorded cane disease epidemics of any importance up to 1907. About this year trouble was again experienced with the Otaheite variety, this time in the Na-

guabo district.[1] The disease here was very clearly a deterioration of a long-planted variety brought about by rind (*Melanconium*) and root disease (*Marasmius, Odontia*), and other unfavorable conditions. The symptoms were characteristic in all respects for these two maladies and no signs of the mottling were seen at any time. The situation was overcome by the introduction of new varieties to replace the white (Otaheite).

It thus appears that although Porto Rico has suffered from severe epidemics of cane diseases in the past, the present peculiar type has not occurred heretofore. Not only has the literature failed to bring out anything suggestive of it, but conversations with old residents who had personal knowledge of the sick cane of 1872–78 does not make it at all probable that the two were the same, at least in so far as visual symptoms are concerned.

Serious cane diseases in other parts of the world.

Practically every sugar-cane growing country in the world has suffered at one time or another heavy loss from disease, deterioration, or a combination of the two. For example, Porto Rico 1872–80, Mauritius 1841, and again in 1872, Java 1882, Antigua and other British West Indies 1895–9. Some of these visitations have been due to unknown causes, others have been designated as rind disease, Sereh, etc. As a matter of fact most of them probably come under the head of deterioration, or possibly in certain ones of degeneration. In a considerable number of these epidemics the Otaheite or Bourbon cane has been involved.

One of the most striking instances of this kind was the running out of this variety over a number of years (1895–9) in Barbados, Antigua, and others of the British West Indies. This has always been ascribed to the rind disease, and was satisfactorily checked by the substitution of new and more resistant varieties, a measure which has served to overcome the various other epidemics as well.

During recent years the Lahaina cane of Hawaii (probably the same as the Otaheite) has been failing, giving rise to what is known as the "Lahaina Trouble." Various agencies have at one time or another been held responsible, top-rot, stellate crystal fungus, poor drainage, senility, and others, but the actual cause is still obscure. New varieties and possible changes in fertilizing and cultivation seem to be the control measures now being tried.

It is apparent that the system which has universally prevailed in all cane countries, at least until serious diseases have appeared,

[1]Data contained in a letter from Mr. H. I. Sewall of Naguabo to the writer.

of growing one variety to the practical exclusion of all others has resulted in all of them, though at different times, in a deterioration of the plants, so decided as to assume the proportions of an epidemic. In each instance secondary factors, such as rind disease and other fungi, have appeared, so that the visual symptoms have varied over a considerable range, though the underlying causes were the same in all. In not one of these epidemics, however, has there been any mention made of symptoms which fit the mottling disease, so that it is not considered likely that it has occurred before in any other part of the world.

Rind disease.

Principally because of resemblances to the "rind diesase epidemic" of the British West Indies particular attention was given to a search for this disease. The drying and shrinking of the stalks from the top downward with consequent death of the leaves and the final production of the innumerable black conidial masses was conspicuously absent, much less being found in mottled fields than occurs in normal fields elsewhere. Not even in abandoned third-phase fields could *Melanconium* be found, except in isolated cases. Near Camuy a field of Rayada of nearly fifty acres was discovered which it had not been possible to cut for the mill and which was being left until the following season. Not a sign of mottling was present, but it was fast approaching total less due to rind disease.

No evidence has been obtained to bear out the theory that *Melanconium* may be present in stalks which appear normal.

Other stalk diseases noted in other parts of the Island, red rot (*Colletotrichum*), brown rot (*Diplodia cacaoicola*), and *Cytospora sacchari* have either been completely wanting, or in such isolated instances as to be negligible.

Gumming.

The question will arise in the minds of many as to whether or not mottling is not connected with the gumming disease (*Bacterium vascularum*) of sugar cane, if not in fact that identical disease. A summary of the symptoms of this latter malady, practically none of which apply to mottling, should clear up this point. Quoting Dr. Erwin Smith (11), "The most conspicuous signs of this disease (gumming) are dwarfing, striping of the leaves, drying of the tops, decay of the heart (terminal bud) and the appearance of a yellow slime or gum in the bundles of the stem and leaves. Many of the bundles are also stained red."

Sereh.

In many respects the still mysterious Sereh disease of Java more nearly approaches the Porto Rican malady than any other. A comparison of the two as to signs and characteristics will not be out of place (again following Dr. Smith's account [11]).

"The Sereh appears at first only sporadically; the year following one finds usually Sereh plants everywhere and the third year the disease occurs in such severity (when no measures are taken against it) that a failure of the crop results." This corresponds very well to the course of the mottling disease. Other signs are also in close agreement, principal of which are the transmission of the disease from old plants to new ones by means of cuttings and the shortening of internodes. On the other hand Sereh is described with a number of points not noted in connection with mottling, important of which are the presence of gum, slime, or crystals in the bundles or parenchyma tissues of the stalk, red staining of the bundles, yellow stripes (not mottling) of the leaves, excessive production of new shoots, production of shoots and roots above ground, the clinging of the leaves beyond the usual time of falling, and the dying of the foliage from below upward so that apparently the top of the cane is less diseased. Certain other points, particularly the inclination to bloom early and the nature of root development, have not been noted sufficiently well to be contrasted. In addition the Porto Rican disease possesses the very characteristic mottling and cankering of the stalks lacking in Sereh.

Every possible cause has been assigned by one worker or another to Sereh, including plant and animal parasites to a considerable number, unfavorable soil conditions, wrong fertilizers, abnormal weather (drouth or excess of water), degeneration, dying of the roots, and improper cultivation practices. The cause is still unknown.

Without, of course, ever having had any experience or direct knowledge of Sereh, the writer is very much inclined to believe that the mottling is a disease of the same nature and that both are due to non-parasitic but otherwise unknown causes, at present designated as degeneration.

The greatest confusion has arisen and will continue to arise between the new disease and the disease or group of diseases commonly referred to as root-disease, "running out" and deterioration. In an endeavor to clear up the situation in this regard, to some extent at least, a subdivision of the latter group into at least two distinct phenomena is proposed. For the present these will be designated as "deterioration" and "root disease," the first non-parasitic be-

yond any doubt, the second parasitic to a greater or less extent. In this paper up to the present point the first has been referred to as deterioration, and in one instance as "the so-called root disease." The second has not yet been touched upon.

Deterioration.

This term is applied to the general unsatisfactory condition of cane so common in Porto Rico and apparently in all other parts of the world as well judging from the literature, which varies from a mere lack of vigor to a "running out." It is readily attributable to long-continued cultivation of one variety, to unfavorable weather, to poor cultivation, and any other factor which tends to reduce the vigor of the plants. Harrison (4), who has given the most extended account of this matter, presents five principle causes for the deterioration or "running out" of cane varieties, basing his conclusions on observations of the downfall of the Bourbon variety in the West Indies. His causes are as follows:

"(1) Lack of vigor induced by continuous cultivation in the same soil.

"(2) Continuous cultivation of the land to the same depth.

"(3) No care being taken in the selection of suitable material for planting purposes.

"(4) Spread of diseases.

"(5) Changes in the varieties themselves."

The first three of these have already been mentioned and are primarily responsible for deterioration, at least under Porto Rican conditions; the fourth has, as far as the present situation is concerned, been eliminated, and the fifth is a rather indefinite statement which applies very well and helps to explain such points as why certain varieties after thriving for a time begin to fail.

As the task at this point is but to make clear the difference between this cane trouble and mottling, further discussion of causes is unnecessary.

The first symptoms as noted in the leaves may readily be confused with those of mottling. In fact, the spots or discolored areas can with certainty be distinguished only by their color, which is of a decided yellow rather than the white or near-white of the mottling disease. They are possibly less linear in shape, but this is not a constant difference. However, even though it be impossible to separate them more clearly in a written description, a study of actual specimens of the two together makes possible their instant

recognition, so that there is no confusion in the minds of those studying or observing the diseases.

A further point of difference lies in the fact that this yellow spotting if such it may be called, attacks the lower leaves first, new leaves issuing from the bud being always of normal color. Yellow-spotted leaves are very subject to *Leptosphaeria* and other leaf-spots, and the leaves very often die prematurely. This condition in the early stages yields to an increase in the moisture supply, and especially to fertilization and improved cultivation. It is not transmissible through the seed except in so far as a general tendency to the trouble is concerned when growth conditions are not of the best.

When the unfavorable circumstances persist, the deterioration becomes more marked, resulting in a dwarfing of the stools, dying of the leaves and roots, and general appearance of unthriftiness. It becomes especially marked in each successive ratoon crop, and if the field be not abandoned an increasingly large number of stools die each season. In these advanced stages the rhizomes and base of the plants will be found thoroughly rotted and permeated by the white mycelium of one or more fungi (*Himantia stellifera* occurs most commonly). It is this situation that has led to the designation of this condition as "root disease" by many writers.

Deterioration is wide spread in Porto Rico, being especially common in its early, or yellow-spotting stage, for instance, where unsuitable varieties are being grown, where cultivation and fertilization have been delayed, in heavy soils, or during periods of drouth. The fact that there is a recovery (that is, the new leaves are normal) from this stage and that the growers have confused it with mottling, probably explains certain persistent claims that the latter disease has been "cured" by fertilization or other measures.

The former has always been a prominent factor in cane cultivation in the western portion of the Island because of drouth and cultural conditions prevailing there, and is still, of course, very much in evidence and still causing heavy loss. Innumerable cases occur where it acts in connection with mottling, but sufficient observations and tests have been made to indicate that it is distinct from the latter malady.

The presence of a non-parasitic type of root disease resulting in deterioration has been recognized by other workers, particularly in Java. Wakker (7) reports an hereditary constitutional disease characterized by yellow spots in the leaves, and Kamerling and Suringer (6) studied a root disease due to a compacting of a heavy soil. Nowell (9) in Barbados apparently recognizes a deterioration

phenomenon of cane, not strictly parasitic, and confuses the Porto Rican mottling with it.

Root disease.

In addition to the above there is another and somewhat similar disease quite clearly, however, parasitic in its nature. Several fungi occur in and about cane stools suffering from this type of disease, *Marasmius sacchari* being the one most commonly held responsible. The stellate crystal fungus (*Himantia stellifera*) and the granular leaf-sheath fungus (*Odontia saccharicola*), the latter probably the perfect stage of the former, are of eyen more common occurrence. As already noted elsewhere (5), the entire matter of the relationships of these various fungi and their connection with root disease of cane is a subject requiring definite experiments under controlled conditions before exact statements can be made.

In typical cases of root disease there is no spotting of the leaves, other than that they are quite susceptible to *Leptosphaeria*. They die back uniformly from the tips and along the margins, the lower ones dying first. For some time, except for the dead and dying roots and leaves, no other symptoms appear. Finally, however, the fungus grows up around the stalks binding the leaf-sheaths quite firmly together with a white mycelial mat. A musty odor is present. Practically none of this disease has been encountered in the territory where mottling prevails.

CONTROL.

In the report of last year on the cane-disease situation a number of recommendations were made. During the season just past most of these have been tried out by the various Centrals and cane growers, and the course of their efforts has been followed in the field work carried on. It has not been apparent that any of the measures tried out to date have been successful, nor in a majority of cases any combinations of them.

Increased fertilization as tried out by the growers has been without effect, although exact experiments carried out in cooperation with one of the Centrals gave promising results, some combinations yielding fifty per cent more merchantable cane than the check plots. The use of fertilizers, of course, under any circumstances will be of assistance only indirectly in so far as it promotes a better growth of cane. Before any recommendations can be made along this line, further tests are necessary.

Liming in addition to fertilization was practiced in at least one

locality. It was not apparent that it had any effect on the amount of disease present. There seems to be a tendency on the part of many growers to consider lime, when it is recommended to them for trial, as a sort of medicine which will in short order remedy the sick cane without the necessity of other measures.

No correlation between drainage or lack of it and mottling exists as far as present studies show. Except for the general observation that lowland fields are less prone as yet to succumb, no relation has been evident between irrigation or a plentiful water supply and the disease. Many growers report more disease in low-lying portions of infected fields. Further observations are necessary.

Considerable emphasis was placed on the necessity of proper preparation of the soil and subsequent cultivation. This will apply very well to ordinary disease conditions, such as root disease or deterioration, but has been quite ineffectual in checking the mottling. Instances have been reported of fields given from five to seven plowings with cultivation in proportion, yet the disease was to all appearances unchecked.

As heretofore burning the trash has been practiced in some fields and in others it has been pulled into the alternate rows as recommended. As far as mottling is concerned, it is immaterial which method is followed, but all other considerations demand the non-burning of trash where replanting is not interfered with. The stand taken last year on this matter of conservation of the trash is not abated an iota.

The pot cultures at the Station as well as all field results show very clearly that dipping seed in Bordeaux mixture is without any effect whatsoever as far as checking the new disease is concerned. It is now a very common practice over large portions of the area in question to dip the seed, and there has been considerable disappointment over the fact that it has failed so completely, although it has always been specifically stated whenever Bordeaux mixture has been recommended that it was effective against the pineapple disease only.

Another point upon which considerable reliance had been placed in checking the epidemic was the use of new varieties. It was evident that the white (Otaheite), striped (Rayada), crystallina, and probably even the caña de vino and Sarangola would be eliminated for all practical purposes, but it was confidently expected that one or more of the new types sent in for trial would show immunity or at least sufficient resistence to make them of practical value. While it is true that certain ones, as noted previously, have behaved bet-

ter than others, not one has yet been found which has given any promise of going through the trial successfully. One of the most disheartening features has been the behavior in several instances of seed of various new varieties sent out from this Station. The plantings were made on new land (in coffee until the present year), and yet a small amount of mottling appeared. When these fields were cut and the seed again planted in new land, a still larger proportion of diseased stools resulted, although seed from any mottled stools had been carefully eliminated. The fields from which this seed originally came at the Experiment Station are still free from the disease. A number of the growers, and some of the Centrals as well, have brought seed from districts well outside the diseased region; but all such, as far as it has been reported upon, has failed to remain free of mottling.

One point has become quite clear in the matter of seed selection. Realizing that practically all seed from all stools showing mottling would in turn produce mottled cane, the majority of the growers have been at great pains to reject all such material when cutting for seed, but have continued to use all the other cane from the same field, with the result that an equal or greater amount of mottling appears in the new field. It is therefore apparent that a varying percentage of the stools of a given field are diseased or have a tendency to be, even though to all outward appearances they are normal. This adds an additional difficulty to any system of control that may be undertaken.

It must now be realized that any effective method of controlling the situation will be most drastic. It will, in effect, constitute a revolution in the cane agriculture of at least the western part of the Island.

In many instances where fields have failed to give a merchantable yield further cane growing for a year or two at least is not advisable and other crops must be taken up, as has already been done to a considerable extent. Cotton, tobacco, and on smaller areas, onions, beans, corn, or other food crops suggest themselves as possibilities at this time. Food crops as a temporary expedient at least should pay well in the present crisis.

In many cases it will be possible to give the land over to pasture grasses (*malojillo*, guinea, or some of the new introductions, such as Natal or Rhodes grasses) and so make a change from cane to cattle. While this change is in progress it may be possible to obtain one or more crops of cane on part of the land by using some of the less severely attacked varieties, Sarangola, etc.

It is, of course, not known, and there is as yet no way of ascertaining how long the land must be rested before returning to cane culture, but at least one full year should be given, after which healthy seed from known disease-free sources should be tried out, preferably on a small scale. In addition the other measures given hereafter should form an important part of the program.

The above scheme applies to those fields so badly diseased that it has become impossible to raise cane at all on them. Where the infection has not reached such a point as to bring the yield below a paying basis, a somewhat different course of action is suggested. This involves a continuation of cane culture, since it is realized that all efforts must be made to maintain the sugar industry.

The ideal state of affairs would be a rotation, in which cane would be the important crop supplemented by a legume to afford some of the humus so lacking in all Porto Rican soils, and to rest the land. Most unfortunately it is not yet possible to do more than give suggestions in this regard. The particular difficulty lies in finding a legume suitable for growing on the large scale which a place in a rotation with cane demands. Various of the velvet beans, cowpeas, and possibly the soy bean should prove acceptable. More data will be available on this point after the experiments being inaugurated by this Station have progressed further.

The problem of finding resistant varieties is one in which the growers can aid most effectively the efforts already under way. All available varieties must be tried out in the hope of obtaining types that will prove resistant in the various sections of the infected country. Under a previous heading there has been discussion of the behavior of the varieties tried to date. Conditions differ so markedly from one district to another that it is hardly possible that one kind will be found satisfactory in all, and hence it becomes of importance that each be tried in as many different localities as possible.

It is perhaps needless to mention the desirability of avoiding absolutely the use of seed from infected stools, and in so far as possible from fields showing even only very small amounts of the disease for reasons previously stated.

Where only a small percentage of diseased stools occur the fight should by all means be kept up to ward off the evil day when infection becomes one hundred percent and there is no salable cane. The means at hand for this effort are several. It must be most emphatically stated that no one of them or even several together will be sufficient but all of them should be used, and with the greatest possible efforts of the grower.

At a convenient time all diseased stools should be dug and removed from the field or at least cut down, and in the former case the holes not replanted for one year. This will prevent any chance of diseased material being taken later for seed.

In cutting for seed take only the Rayada, Sarangola, or other canes which have shown the greatest resistance, discarding entirely the white and bamboo. This will eliminate in the course of a year or two these unsatisfactory types.

All seed should be dipped in Bordeaux mixture, not that this prevents mottling but that it does prevent other disease, aids in giving a better germination, and makes possible a more careful selection of the seed pieces.

Prepare the land thoroughly. Probably the most important factor in this connection is deep plowing, followed by sub-soiling where possible. Plowing at the same depth year after year creates a condition known as hard pan just beneath the layer of soil turned over by the plow. This layer prevents the passage of rain water into the soil and so increases surface run off and consequent washing of the soil. Similarly it prevents soil moisture from passing upward to the cane roots in times of drouth. The beneficial effects of breaking up this hard pan will be most noticeable.

Cultivation as often as necessary to keep down the weeds and as complete fertilization as present conditions make possible should be important parts of the program.

In other words all those points which go to make up thorough cultivation, combined with selection of seed to eliminate all diseased and weak material, constitute the present recommendations.

In conclusion the recommendations given heretofore may be briefly summarized as follows:

1. Fields which have been so badly diseased as to fail to yield on a paying basis should not be replanted to cane for at least a year, preferably longer. They should be used for pasture or other crops, particularly food crops.

2. Efforts should be made to initiate a rotation, and one which will include a legume, so as to maintain the sugar industry.

3. Continued trials must be made with new varieties.

4. Diseased seed must be avoided as well as any seed material from badly diseased fields.

5. Where the disease has not gained great headway, it should be fought by careful seed selection, treatment of seed, use of hardy varieties, deep plowing, fertilization, cultivation, and all other measures tending to produce a crop of healthy, resistant cane.

LITERATURE CITED.

(1) Acosta, José Julián, Grand-Court, C. Grivot, y Stahl, Agustín.

1878. Informe dado a la Excelentísima Diputación Provincial sobre la Enfermedad de la Caña de Azúcar en el 4º. Departamento de la Isla de Puerto Rico. Mayagüez.

(2) Fernández Umpierre, Manuel.

1884. La Caña Dulce, o de Azúcar y su Enfermedad en Puerto Rico. *In* Manual Práctico de la Agricultura de la Caña de Azúcar, San Juan.

(3) Fitch, C. L.

1910. Productiveness and Degeneracy of the Irish Potato. Bul. 176, Col. Agric. Exp. Sta., figs. 8.

(4) Harrison, J. B. *et al.*

1912. Varieties of Sugar-cane. *In* West Ind. Bul., v. 13, no. 2, pp. 177–217.

(5) Johnston, J. R., and Stevenson, John A.

1917. Fungi and Diseases of Sugar Cane in Porto Rico. *In* Journ. of Dept. of Agric. of P. R., v. 1, no. 4, pp. 177.

(6) Kamerling, Z, and Suringar, H.

1900. Oenderzoekingen over onvoidoenden groei en ontifdig afsterven van het rilt als gevolg van wortelziekten. Medeel. van het Proefsta. vor Suik. en West-Java. No. 48.

(7) Kamerling, Z.

1903. Verslag van het Wortelrot-Oenderzoek; Soerabaia.

(8) López Tuero, Fernando.

1895. Enfermedad de la Caña de Azúcar. *In* Caña de Azúcar, pp. 105–123. San Juan.

(9) Nowell, W.

1917. Sugar-cane Diseases in Porto Rico. *In* Agric. News of Barbados, v. 16, no. 393, p. 158.

(10) Orton, W. A.

1914. Potato Wilt, Leaf-Roll, and Related Diseases. Bul. no. 64, U. S. Dept. of Agric., pls. 16.

(11) Smith, Erwin F.

1914. Bacteria in Relation to Plant Diseases. Volume 3, pp. 3–80.

(12) STEVENSON, JOHN A.
1917. *In* Fifth Report of the Bd. of Com. of Agriculture of P. R., p. 58–70.

(13) STEVENSON, JOHN A.
1917. Enfermedad de la Caña de Azucar en Puerto Rico. *In* El Mundo Azucarero, v. 5, no. 1., pp. 19–24, figs. 10.
In English *in* La. Planter, v. 59, no. 5, pp. 76–78.

(14) STEVENSON, JOHN A.
1917. La Nueva Enfermedad de la Caña. Circ. 11, Insular Exp. Station of P. R., pp. 1–12.

(15) STEWART, F. C.
1916. Observations on Some Degenerate Strains of Potatoes. Bul. 422, N. Y. Agric. Exp. Sta., pp. 319–357, pls. 12.

(16) TEMPANY, H. A.
1909. The Passing of the Bourbon Cane in Antigua. *In* West Ind. Bul., v. 10, no. 1, pp. 34–54.

(17) WORTLEY, E. J.
1915. The Transmission of Potato Mosaic Through the Tuber. *In* Sci. n. s., v. 42, no. 1083, pp. 460–1.

MINOR CANE DISEASES AND NOTES.

Practically all of the work of the year on cane diseases has been in connection with the mottling disease investigation. This has involved a number of fungi as will have been noted in the foregoing account. Further notes and observations along this line have been included in the paper on cane fungi and diseases now in press as number four, volume one, of the *Journal of the Department of Agriculture of Porto Rico*. Only one topic remains for discussion at this point.

Brown rot (*Diplodia cacaoicola* P. Henn.).

This fungus has been observed to be of fairly common occurrence on dead seed pieces or thoroughly rotted stalks, and less often has been collected where it was the initial cause of a rot of isolated stalks. One case was brought to our attention in which on a limited scale the fungus was doing considerable damage. A small experimental planting had been made of D–625 and at about the age of ten months it was attacked by disease. Some stools were completely infected, while in others from one to several stalks only were killed. It was estimated that twenty-five per cent of the stand was infected.

The only external symptom was the withering and dying of at-

tacked stalks from the top downward, in no way different from the death of a stalk from any one of many other causes.

Internally there was found a very characteristic rot, which at once distinguished the disease from any other. The rotted areas extended from the top downward, rapidly covering the entire length of the stalk and attacking the vascular bundles first, which became deep red in color. The discoloration soon became uniform throughout the central pith region, being then bordered by an outer periphery of normal tissues. The diseased tissues were rubbery in consistency, lacking in juice, and rapidly turned brown on exposure to the air. The rot finally worked through to the surface of the stalk, producing irregular brown, sunken patches on the internodes which in time coalesced to include the entire stalk. Fruiting bodies were not formed until the canes were thoroughly rotted and dried out, and have not yet occurred on specimens kept in the laboratory after nearly four months. Tissue cultures have given pure cultures of the fungus. Infected seed pieces were planted and have germinated normally, the shoots at this time (four months) being still healthy to all appearances.

This rot is readily distinguished from that caused by *Colletotrichum* by the deeper color, greater uniformity of the infected areas, the brown color appearing on exposure to the air, and the lack of the characteristic white patches occurring in advanced red-rot cases.

This disease can be readily kept in check by the use of resistant varieties, D–625 being notoriously an undesirable cane.

CITRUS DISEASES.

While the usual number of trips of inspection have been made to the various citrus groves, actual work on citrus diseases has been confined for the most part to scab and the fruit rots. Notes on other diseases have been reserved for a proposed complete publication on this subject.

CITRUS SCAB (*Cladosporium* [*?*] *citri* Mass.).

Citrus scab continues to be, on the whole, the cause of the heaviest loss sustained by the citrus growers of the Island. During the year past it has not only continued prevalent in all groves previously attacked, but has spread to various new ones and has appeared in some districts hitherto practically free.

Weather conditions during the first part of the season (February-March) were rather unfavorable for scab infection, and even where no measures were taken against it quantities of fruit came

through untouched by disease. There were, of course, certain groves which had scab, apparently, in spite of weather conditions. In this connection it is common to find in most groves isolated trees which are most susceptible and which under all conditions bear practically only scabby fruit. The elimination or budding over of such trees has been advised at all times.

Later on (April) a second bloom was accompanied by wet weather and a greatly increased amount of scab. Examinations made in May quite clearly showed there was a great difference in amount of infection on the fruit of the two blooms.

Field work in addition to the observations made from grove to grove included the taking of notes on the prevalence of scab on all trees in certain blocks as had been done in previous years, the tagging of specific clusters of fruit to permit the study of time and progress of infection, and an experiment in the application of finely ground dry sulphur. Details of the work carried on will be mentioned but briefly, since it is proposed to issue at once a circular covering present knowledge of the disease including suggestions for its control.

On certain blocks of trees notes as to the amount of scab in each individual tree have been taken for several seasons. Some interesting data has been secured on the recurrence of scab on certain trees from year to year, and its absence on others, as well as other facts of a similar nature. During the season a series of tags (considerably over one hundred in number) was placed on clusters of fruit buds throughout a representative grove and the development of the flowers and fruit followed through the season. The percentages of fruit set and the number finally maturing were secured, as well as the approximate time of infection by scab. No variation from statements made in previous reports as to the size of fruit susceptible to attack appeared. It is thought preferable to continue this work for at least another season before reporting in detail.

Dusting experiment.

In New York State considerable work has been done with various powdered materials for the control of apple diseases and insects, and to a less extent for diseases of other fruit trees and shrubs. Finely ground sulphur and powdered lead arsenate, with some inert substance such as talc or lime, to reduce the cost of the mixture, have been most commonly used. Very favorable results have been reported in some instances, so that for this reason and because of certain evident advantages of a dust application over a liquid spray

as thorough trials as possible were instituted, to ascertain any possibilities the method might have under Porto Rican conditions.

The great difficulty in all attempts at controlling scab in Porto Rico has been the irregularity of the bloom periods, it being usual for two separate heavy blooms to occur between January first and June first with straggling bloom and new growth at practically all times of the year. The result is that although scab attacks the fruit and leaves during comparatively a short portion of their development only, the fact that new bloom and leaves are coming on in all seasons serves very readily to keep the disease active and make control correspondingly difficult.

To add to this trouble is the fact that in many groves there is a scarcity of water, often amounting at a critical period to a total lack for spraying purposes, and furthermore that in the average grove it is impossible to cover all the trees as thoroughly and as often as the situation demands. Rather frequent applications during the susceptible period are necessary and it is rare indeed to find a grove properly equipped with sufficient spraying machinery to permit of getting around even once a week.

As an additional point of considerable importance in certain groves, blocks of trees have become so grown together that a power sprayer is out of the question and spraying has been a matter of hand or barrel machines (a slow, expensive, most unsatisfactory method) or has been omitted entirely with a consequent increase in the percentage of low-grade fruit.

It was quickly seen that many of these difficulties would be overcome by the use of applications in dust form, provided, of course, the sulphur or other material used proved effective when applied in this manner. The dusting machines available were effective, comparatively cheap, easy to operate, and above all so small as to pass through practically any block of trees on the Island without the necessity of the pruning out of large limbs, or without damage to the trees.

For the experiment a block of trees, the past history of which from the scab standpoint was known, was selected. The material used was finely ground sulphur, and throughout this test it was used pure; that is, without any diluents, such as talc or lime. It was not at all certain that the dust would be of any benefit so it was considered advisable to work with a full-strength material at first until this point was settled. If biting insects had been present in injurious numbers, powdered lead arsenate to the amount of ten per cent would have been used.

Seven rows of trees, twenty-five to a row, were used, the two

rows to the windward side being left as checks. An adjoining block of trees of the same age and condition sprayed with liquid lime sulphur were also used for comparison. The five rows dusted were gone over from one to six times between January 26th, when the first bloom was in the early bud stage, and May first, when the fruit of the second heavy bloom was about past the danger point in size; that is to say, certain trees received six applications, others five, and so on, some having being treated but once. Notes were taken as to weather conditions, time of blooming of each tree, rate of application, amount of material used per tree, comparative costs and the usual other points of importance in the same connection.

Mechanically, the operation of dusting was very satisfactory, the material was thoroughly and easily applied to each tree and remained on the leaves for a surprisingly long time, and most important of all a very large number of trees could be covered in a very short time. Practically the only limit was the rate of speed at which the machine could be moved, oxen, the usual animals available, being rather slow than otherwise. Under normal conditions thirty acres and even more can be covered in a day.

At no time, however, was it apparent that any good was being accomplished in the checking of scab, and at the conclusion of the experiment a careful tree-to-tree examination was made to settle this point. The record made showed quite clearly that those trees which were susceptible as shown by the records of the several seasons bore scabby fruit to a large degree, and those that were not so inclined remained free of the disease, irrespective of whether they had received sulphur dust or not. The tree with the largest percentage of scabbed fruit received six dustings.

Because of this unfavorable result no further mention will be made of comparative costs or other data secured.

In another grove dusting operations in which the sulphur was diluted with talc in various proportions were followed and the results checked. It was not apparent that any benefits, as far as control of scab was concerned, were secured.

Much had been hoped for from dusting, but it has, so far at least, failed most decidedly to come up to expectations, and it must be still considered as in the experimental stage only.

FRUIT ROTS.

In order to obtain direct information as to the nature of fruit rots as they appeared upon arrival of the fruit in New York City, the writer during the month of October made an inspection on the

docks of four shipments of grapefruit and oranges. Observations were made during the operation of repacking in the course of which all rotted fruits are discarded. Those handling the fruit recognized several types of rot, principal of which were a soft rot, and a stem-end rot, with or without a juice exudate, but all were due to the one fungus *Diplodia*, which has been observed and studied in the laboratory and the packing houses here on the Island.

Very little of the Penicillium rot was noted, so little in fact as to be negligible. Whether this was due to the season of the year at which the examination was made or to increased care in handling is not clear, but the writer inclines to the belief that it is the latter, basing this opinion on other information at hand.

The amount of rot varies greatly with the season of the year and the grove in which the fruit originates as well as upon other conditions. One of the important factors and one as yet uncontrollable is the matter of ventilation and temperature relations on board ship, fruit suffers a higher percentage of rot on certain vessels than on others and is apparently more apt to decay when transported in proximity to sugar.

The control of the less important type of rot due to *Penicillium spp.* (blue and green mold) is well understood and has been treated in detail in various other publications. The checking of losses from *Diplodia* is much more difficult and involves a number of points other than care in picking and packing. Briefly stated, these include the elimination of scale insects which are very prevalent in Porto Rican citrus groves, careful pruning out of dead wood a common source of infection, the cleaning out of gumming areas or trunk cankers, and the prompt disposal of drops and cull fruit. The practice of burying such material in shallow pits in the grove itself is objectionable, since the fruits are easily re-exposed to the surface by cultivation or other means and often at the most favorable time for the dispersal of spores.

CROWN ROT OF SEEDLINGS (*Sclerotium Rolfsii* Sacc.).

In one instance loss was occasioned in a grapefruit seed bed by an attack of *Sclerotium Rolfsii*, a fungus also responsible for diseases of sugar cane (red-rot of the leaf sheath), pepper, eggplant, tomato, and other crops in Porto Rico. In this case the seedlings were attacked when they were from three to six inches in height and were speedily girdled at about the ground line, death resulting. It is possible that other unfavorable conditions were present, since although the fungus is very abundant everywhere no other complaints

of loss in citrus seedlings from this cause have been received. Careful drainage, and thorough cultivation are recommended as measures for avoiding loss from this disease.

MISTLETOE (*Dendropemon* Spp.).

A most interesting parasite of citrus trees has been observed in a number of localities particularly in the western portion of the citrus district. This is not of the fungus class as are the other parasites but is a true flowering plant and of the well-known group known as the mistletoes.

The sticky, pulp covered seeds are carried by birds to the limbs of the citrus trees where they germinate, sending their rootlike processes into the tissues of the host, so taking up their parasitic course of life. Quite large plants result which not only take considerable from the tree in the way of moisture and mineral constituents, but cause the death of limbs and produce an unsightly appearance as well.

At least two species have been collected on Citrus (*Dendropemon bicolor*, and *D. caribaeum*) both of which also occur on a considerable range of other hosts, some of economic importance. As a measure of protection to the citrus the pruning out of infected branches or removal of young plants is feasible and the destruction of nearby trees of other species, of no particular value and which harbor the parasites, is recommended.

VEGETABLE DISEASES.

[*By* JOHN A. STEVENSON AND R. C. ROSE.]

A considerable amount of work has been carried on with some of the more important vegetable diseases, the increased trial plantings at the Station making this possible. On a number of the diseases data suplementary to that published in a recent paper[1] in the *Journal of Agriculture* has been secured, and some diseases not previously reported have been found. A number of experiments in control have been carried out.

BEANS (*Phaseolus vulgaris*).

Bacteriosis (*Bacterium phaseoli* Erw. Sm.).

This disease was noted as occurring last year, but of minor importance. During the season just closed, however, it has been one of the most serious of the bean diseases. The organism causing the

[1] Stevenson, John A. Diseases of Vegetable and Garden Crops. *In* Journ. Dept. of Agric. of P. R., v. 1, no. 2, pp. 93–117.

disease attacks leaves, stems, and pods, but has been most severe to date in its effect on the leaves. It produces water-soaked areas, irregular in shape, which later become dull brown. The leaves are soon killed and complete defoliation often results. The black Venezuelan and some of the native types have been much more resistant than the various northern wax-bean varieties.

The presence of leaf-hoppers and other insects in great abundance has been the chief factor in the rapid spread of this disease and the combination of the two has played havoc with several plantings. The disease has been worse during wet weather.

A number of spraying tests were carried out, but for the most part gave only negative results. In these spraying was at weekly intervals. On one small plot of Curry's rust proof, applications were made biweekly from the time the plants were a few inches high until they were through bearing, nine sprayings in all. Because of heavy insect infestations, Blackleaf 40 and lead arsenate were applied to the entire plot. One row was sprayed with sulphocide (recommended strength), one with Bordeaux (4–4–50), and one row left as a check. Bacteriosis was the only disease present. The yields in green beans were proportionally as follows:

Check row	No pods set.
Bordeaux	4 lbs. 5 oz.
Sulphocide	9 oz.

A result very clearly in favor of Bordeaux. The check row was completely defoliated by the time blossoming began, and the sulphocide row soon after. This test is merely indicative of the need of further work. It is doubtful whether this number of sprayings, at least at current prices for materials, would be an economic proposition. This disease will be more satisfactorily combated by the use of disease-free seed and the more resistant varieties, which are the usual recommendations given.

Downy mildew (*Phytophthora terrestria* Sherb.).

This disease has already been reported[1] but without any specific determination being given. It was quite apparent from a study of the fungus that it was distinct from that producing downy mildew of lima beans (*Phytophthora phaseoli* Thax.). It had been impossible to place it in any described species until the appearance of a paper by Sherbakoff in which he describes *Phytophthora terrestria* n. sp. causing a rot of tomatoes called the buckeye rot. A comparison of the Porto Rican fungus with his description makes it

[1] Loc. cit.

very probable that they are the same. This probability has been increased by the finding of tomatoes adjacent to the beans rotted with what is beyond any question the "buckeye rot."

The course of the disease during this season has been the same as reported for the previous year. It appeared during wet weather and was most virulent as long as it continued. With the advent of dry weather it ceased to spread, except along irrigation lines.

The uncertainty of its appearance makes control measures difficult if any were to be attempted, such as spraying. The ultimate solution will be, as with most other bean diseases, the growing of resistant or immune varieties. For instance, it has already been noted that the most susceptible types have been the introduced northern ones, and certain others, even when in parallel rows, have not been attacked.

CUCUMBER (*Cucumis sativus*).

Downy mildew (*Peronoplasmopora cubenis* [B. & C.] Clinton).

As before, this disease has been the principal obstacle to successful cucumber culture. An attempt was made to check it by the combined use of fungicides and the training of the plants on a wire trellis. Both Bordeaux and sulphocide were used, and while some benefit was derived from their use it was not sufficient to be of economic importance.

EGG-PLANT (*Solanum melongena*).

Wilt (*Bacterium solanacearum* Er. Sm.).

This disease, the presence of which was doubtfully reported last year, has appeared with considerable virulence, not only on this host but on the tomatoes as well. As before, diagnosis has been complicated by the presence in serious amounts of nematodes and *Sclerotium Rolfsii*. Cases observed have been typical as to symptoms, manner of spread, and other characteristics, following Dr. Erwin Smith's account. In the present instance the lacewing fly (*Corythaica monacha*) has apparently been responsible for a rapid spread of the disease. A bacterium was isolated from the browned vascular region of the stalks of diseased plants and has reproduced the disease upon inoculation into healthy plants within eight to nine days.

A considerable range of other solanaceous plants, many closely related to the egg-plant and tomato, occur in Porto Rico and further work with the wilt will be necessary to determine the susceptibility or immunity of the more important of these. *Solanum torvum*, for

example, has been suggested as a stock for grafting egg-plant, but there is no data as to its behavior with respect to *Bacterium solanacearum*. The problem of insects as carriers also presents possibilities of interesting work as well as being of considerable economic value. Finally, a definite comparison of the symptoms of the disease and the characters of the causative organism must be made with description of wilt as it occurs elsewhere.

Stem canker, fruit rot (*Phomopsis vexans* [Sacc. & Syd.] Harter).

In one planting of eggplant this disease in the form of leaf spots and stem cankers, particularly the latter, caused considerable loss. Young plants of two varieties (Improved Purple Thornless and Florida High Bush), but recently set in the field, were attacked. In nine rows (322 plants) one hundred and forty-one plants (43 per cent) were dead or dying. Many of the others were also infected to a less degree, remaining more or less stunted and producing very little fruit. Spraying with Bordeaux was without effect. Other plantings during the year were not infected.

MUSK MELON (*Cucumis melo*).

Downy mildew. (*Peronoplasmopora cubensis* [B. & C.] Clinton).

This has been the chief reason for the failures experienced in attempting to grow American musk-melons in Porto Rico. The vines are attacked very early in their growth and the leaves are destroyed nearly as fast as they unfold, so that ultimately the plants consist of merely a long stem with only a few green leaves at the tip. Blossoms are produced but fail to set more than one or two fruit to a plant. The plants die before the fruit matures. The system of trellises combined with Bordeaux spraying (4–4–50) at weekly intervals was tried but without success. A variety of the native melon which is under trial has been quite resistent and gives promise of being a good foundation type from which to develop satisfactory varieties.

Gray blotch (*Mycosphaerella citrullina* [C. O. Sm.] Gross).

This is the first report of the occurrence of this disease in Porto Rico. Melon vines were first seen infected when about half grown, and from this time on the disease spread very rapidly. The combined effect of this disease and downy mildew has proven most disastrous for the host plants.

The *Mycosphærella* disease attacks the stem of the vines most commonly at the nodal regions, which results in the wilting and

death of the leaves arising from each node. Infected areas are somewhat corky and yellow in color, finally becoming gray to dirty white. The fruiting bodies are of two kinds (pycnidia and perithecia) and are produced in these blotches.

The disease has also been noted on a variety of summer squash, but has not attacked to date native melons adjoining.

TOMATO (*Lycopersicum esculentum*).

Wilt (*Bacterium solanacearum* Er. Sm.).

As noted under eggplant diseases, wilt, although reported by other workers for Porto Rico, has not been in evidence in our studies until the present season, when however, it has been very prevalent. Infected plants showed a wilting which increased day by day, with only partial recovery at night, until death resulted. The vascular tissues were stained brown and swarmed with bacteria. The characteristic knots and projections were noted on the stems of diseased plants. No varietal differences in susceptibility have been marked. As already outlined, further studies on control measures and the question of other possible hosts are necessary.

Root-knot (*Heterodera radicicola* [Greef.] Mül.).

This pest, which attacks a wide range of host plants, is especially severe as an enemy of the tomato. Not only are the roots completely distorted and deformed, stunting and greatly weakening the plants, but the way is paved for the entrance of various diseases, in particular wilt and crown rot (*Sclerotium Rolfsii*), so that as a result of the combined work of these various agencies heavy loss is experienced in most tomato plantings.

A year ago counts revealed one hundred per cent of seriously attacked plants. For this year's plants the soil was sterilized by steam, so that normal growth was possible at least until they were all in the field. An examination was again made at the end of the growing season of the condition of the roots and a considerable improvement noted, only thirty-five per cent being severely attacked. These were not on the same field as the previous crop, but nematodes are apparently quite uniformly distributed.

Buckeye rot (*Phytophthora terrestria* Sherb.).

This recently described disease[1] was first noted last year and was referred to as soft brown rot. It has not been prevalent in

[1] Sherbakhoff, C. D. Buckeye Rot of Tomato Fruit. Phytopath, v. 7, no. 2, pp. 119–129. April, 1917.

the season just past, isolated fruits only, generally those in contact with the soil, being attacked. The symptoms of the rot were typical of those given for the Florida disease.

Leaf diseases and fruit rots.

Plantings at all times have been quite severely infected by leaf spot (*Septoria lycopersici*). Leaf mold (*Cladosporium fulvum*) was present on the first planting (Oct.-Jan.) and there were small amounts of black spot (*Phoma destructiva*), fruit rot (blossom end rot, and *Collectotrichum phomoides*).

A rather extensive spraying experiment was inaugurated on the first plantings of tomatoes (Livingstone Globe and Trophy), the materials used being Bordeaux mixture (4–4–50) and sulphocide. Lead arsenate was used to check certain biting insects. Sulphocide was later dropped because of lack of material and absence of any observable results. The small amount of fruit rot present in the field removed one of the chief reasons of the experiment. Bordeaux sprayed plants had somewhat less leaf spotting and remained green longer. The number of sprayings varied from three to eight. Upon calculating the average yield a difference was found in favor of the sprayed plots, but it is very doubtful if the increase was sufficient to pay for the increased expense of the spraying operations and cost of materials.

A number of other spraying tests were made, not only on tomatoes but on pepper, eggplant, okra, and other vegetable crops as well, but results have been quite disappointing. It appears that if applications are made at such times and in such number as recommended in the north no results are obtained in checking disease, while if sufficient sprayings are given to accomplish this end the practical limit is exceeded. The control of a majority of the diseases of field and garden crops will be a matter of proper cultivation and resistant or immune varieties.

MINOR DISEASES AND NOTES.

CASTOR BEAN LEAF SPOT (*Cercospora ricinella* Sacc. & Berl.).

The castor-bean plant (*Ricinus communis*), locally known as higuereta, is not grown on a commercial scale, but occurs quite wide spread in gardens and as an escape, especially along road-sides and in waste places. It is very subject to a leaf spot which is at times serious enough to cause partial defoliation. The spots are usually numerous, circular to subcircular, brown in color at first, or pur-

plish, and finally gray with a well-defined slightly raised purple margin, fruiting on the lower surface.

ROSE LEAF BLOTCH (*Actinonema rosae* [Lib.] Fr.).

This disease of the cultivated rose (*Rosa* spp.) has not been reported before from Porto Rico. One variety only was found attacked and that one not seriously. The disease is characterized by more or less irregular brown to black spots on the upper surface of the leaflets, varying from a few millimeters in diameter to an extent covering most of the infected leaflet. After a time the spots become dull gray at the center and pycnidia (fruiting bodies) are formed. The perfect stage has not yet been encountered on Porto Rican specimens. Diseased leaves turn yellow and fall prematurely, and serious defoliation may result.

RUST OF SPANISH CARNATION (*Ravenelia Humphreyana* P. Henn.).

This rust has been reported from Cuba and Jamaica on this host (*Cæsalpinia pulcherrima*), but has not been known heretofore in Porto Rico. In the present case it caused defoliation of a considerable number of the young plants in the nursery which had become pot-bound. The fungus was characterized by numerous brown pustules on the underside of the pinnæ of the leaves which very rapidly turned yellow or brown and dropped. A new crop of leaves produced after defoliation has so far remained free of the disease.

LEAF SPOT OF THE COROZO PALM (*Cercospora acrocomiae* sp. nov.).

This leaf spot has been under observation for a number of years at Río Piedras. The *Corozo* palm (*Acrocomia media*) is the only host so far as noted to date. The pinnæ of older leaves are attacked quite uniformly, and it is quite common to find all or parts of the leaves prematurely killed by the attack of this fungus. *Pestalozzia palmarum* Cke, is common on the same host, often associated with it at times in the same spot, but as a general rule the spots produced by the two fungi are sufficiently distinct as not to be confused.

CERCOSPORA ACROCOMIAE sp. nov.

Primary spots amphigenous, few, usually 1–8 per pinnæ; but areas between finally dying so as to make large continuous areas; regular, oval, with definite margins neither raised nor sunken, .8–1.5, rarely 2 cm. long by 3–6 mm. broad, rarely wider, at first red brown, then tricolored, a central oval gray area (.5–3 mm. × 2–6 mm.), enclosed by a dark-brown band, 2–3 mm. wide, with an outer more

or less irregular red-brown area, often not completely encircling the central portions. Conidal fascicles hypophyllous, numerous, confined to the central gray area, often in two distinct lines; conidiophores many to each fascicle, brown to olive brown, 1–2 septate, erect to reclining, concolorous with the conidia, 32–70×5–8 mu. Conidia 3–9 septate, long clavate, sometimes slightly curved, apical cell rounded, brown, often constricted at the septæ, 55–120×8–12 mu.

PORTO RICO. Producing spots on leaves of *Acrocomia media*, Río Piedras, July 1914, 2090, Feb. 1912 (Johnston), 4206, July 1917, 6604 (type).

BROWN LEAF SPOT OF PALM (*Pestalozzia palmarum* Cke.).

This is a very common disease of the leaflets or pinnæ of a number of the common palms of the Island, it seldom being serious enough, however, to cause appreciable damage except in the case of plants weakened by unfavorable growth conditions. Pot-bound plants in the nursery have been especially subject to it. The spots are amphigenous, dull brown, darker below, irregular, angular, up to one cm. in diameter, often coalescing to form large continuous areas, finally gray at the center, in which area the acervuli occur, more commonly on the upper surface. The fungus has been collected on the following hosts: Coconut (*Cocos nucifera*), ornamental date (*Phœnix reclinata*), corozo (*Acrocomia media*) and the betal-nut palm (*Areca catechu*).

LEAF SPOT OF PAPAYA (*Pucciniopsis caricae* Earle).

This is at times a serious disease of the papaya (*Carica papaya*) and is commonly present on all plants to a greater or less extent. Damage results from the killing of the leaves, which may at times amount to practical defoliation. The spots are very numerous, circular to subcircular, small 1–2 mm. in diameter, rarely coalescing, but occurring so plentiful as to practically cover the leaf, black in color beneath due to the sporodochia which cover the spots uniformly, dull brown above, the discoloration on the upper surface not showing until some time after infection occurs. The fruiting pustules are commonly overrun by a parasitic white fungus, but not in time to be of any help in checking the disease.

In addition to this leaf spot a trunk rot has been noted in isolated instances. A *Fusarium* sp. was the only fungus present and was fruiting extensively over diseased areas. A soft rot ensued, rapidly girdling the trunk and causing death.

ENTOMOGENOUS FUNGI.

Porto Rico has proven to be a most favorable region for entomogenous fungi; that is, the fungi which attack insects. They are to be particularly noted in all citrus groves parasitic on the various scales, and to a less extent on other types of insects. The red-headed (*Sphaerostilbe coccicola*), white-headed (*Scoleconectria coccophila*), pink-headed (*Microcera fujikuroi*), black (*Myriangium duriæi*), and two forms as yet undetermined are exceedingly common, and aid greatly in keeping the scale pests in check. Observations have shown that while they attack readily under Porto Rican conditions, reappearing on the trees, for instance, after Bordeaux mixture has been used within a surprisingly short time, yet it is but too often true that they do not overcome the scales in time to prevent serious damage to the trees. For this reason in all cases it has been advised that proper spraying measures be taken to check the scale wherever it threatens to be serious, and that no dependence be placed upon the fungi. With this in mind, and furthermore because the fungi are always present to an extent which permits them to cover the grove as soon as conditions are favorable, no experiments in artificial introduction of any of these forms have been attempted, nor is such a course recommended. An attempt was made over a period of several years with the green muscardine fungus (*Metarrhizium anisopliæ*), an enemy of certain beetles and their larvæ, but without any apparent success, as far as creating an epidemic was concerned.

Notes on entomogenous fungi, now described for the first time, or not before reported from the Island, are given below.

Pink scale fungus (*Tuberculariа coccicola* sp. nov.).

This fungus has been under observation for some time and attempts have been made to connect it with some form already named but without avail. It does not occur through the various groves with the same uniformity that other similar fungi do, *Sphaerostilbe*, for example, but in most instances where it has been seen it has been present in great abundance. It has been noted as a general rule that, where its hosts because of a wind-swept condition of the grove or other reasons have overrun the trees, the *Tuberculariа* is most common, but attacks only after the scales have done considerable damage. Hence it is not believed that it is very virulent toward its hosts, for it certainly does not gain any headway until the scales have become so abundant as to be dying naturally in large numbers. No dependence can be placed upon this fungus, at least as a means

of checking scale. The purple scale (*Lepidosaphes beckii*) and the white scale (*Hemichionaspis minor*) are the only hosts observed to date.

It is almost always associated with the white-headed fungus (*Scoleconectria coccophila*), the red-headed (*Sphaerostilbe coccicola*), the pink-headed (*Microcera fujikuroi*), and more rarely with *Myriangium*. These occur on the same branch or leaf, but never on the same host insect.

TUBERCULARIA COCCICOLA sp. nov.

Sporodochia scattered or aggregate, superficial, pulvinate, compact .5–4 mm., averaging 1–2 mm., sometimes uniting irregularly, grenadine pink to safrano pink,[1] fading to dull white with age, with margin regular, not setose; conidiophores crowded, hyaline, septate, smooth, 1.5 x 15–36 mu.; conidia not in chains, but in dense masses on the sporodochia, pink in mass, hyaline under the microscope, ovoid to cylindric, non-guttulate, 1.5–2 x 2–4 mu.

Porto Rico. On *Lepidosaphes beckii*, and *Hemichionaspis minor* on leaves and twigs of *Citrus decumana* and *Citrus sinensis*, Espinosa, Dec. 1914, 2443, Jan. 1917, 6185, March 1917, 6366 (type); Pueblo Viejo, April 1917, 6411; Río Piedras, June 1916.

Septobasidium spongia (Berk & Curtis) Pat.

This is a very striking form which occurs quite extensively in the citrus groves. It has been found on the twigs, leaves, branches and to a limited extent on the trunks of grapefruit (*Citrus decumana*). It has always been found growing over the purple scale, and to some extent the white scale, and the debris associated with colonies of these insects. It is not likely that it is parasitic on these hosts to any very great extent, but rather that it gains a foot hold on dead individuals and the debris around them, and then kills the remainder of the colony by smothering them. No cases have been observed where it could be said to have been of any benefit in controlling the scale.

The characteristic irregular, fungus patches are medium brown in color, composed of loosely interwoven coarse hyphae, and vary in shape and size very greatly, from 1—2 mm. to 6—8 cm. in diameter. On the leaves the patches are quite often nearly circular, on the twigs and branches irregular, often completely enclosing the smaller twigs and extending for some distance. They are readily separable from the substratum, especially after drying. At a later stage of growth the center of the larger masses becomes spongy in

[1] Ridgway. Color Nomenclature, Plate II.

structure—that is, more compact than the loose weft of fungal threads above mentioned. There is no change in color. This is the fruiting or reproductive stage, and the Porto Rican specimens have been the first fertile ones found to date. The determination was made by Dr. Burt of the Missouri Botanical Garden.

Specimens have been collected at Espinosa, Campo Alegre, Bayamón, Río Piedras, and Pueblo Viejo. It occurs in all of the citrus districts of the Island.

Sporotrichum globuliferum Speg.

What is apparently this wide-spread fungus has been noted attacking several different insects. In no case was there a luxuriant growth of mycelium covering the entire insect, but for the most part a scanty fringe around the margin of the host only. Infected insects were quite firmly cemented to the substratum. For the most part individual specimens only have been encountered, but in the case of the Drosophilid flies small epidemics apparently occurred and large numbers of the victims were found on the under sides of grapefruit leaves. Specimens examined have been, Río Piedras, thrip on bean leaf (*Smyth*); Espinosa, Drosophilid flies, (*Stevenson*); Bayamón, Drosophilid flies (*Cotton and Morrison*); Río Piedras leafhoppers on bean leaves (*Cotton*).

Cordyceps dipterygena B. & Br.

This is the first true *Cordyceps* reported from Porto Rico. It also occurs in other parts of the world but is quite rare. The host insect is cemented firmly to leaves (generally the under surface) or twigs, and as far as collected to date has been found on grapefruit only. The fungus appears as gray horns growing out from various parts of the host body, often as a pair arising from the region of the halteres. Most of the specimens taken were in the *Isaria* or imperfect stage only, but one perfect specimen was obtained bearing globular heads at the ends of the horn-like processes. It has been taken at Espinosa several times, and at Río Piedras twice. The host has been *Chrysomyia macellaria*, a common fly, where it has been determinable.

DISEASES OF THE YEAR.

The following is a list of the plant diseases observed or reported during the year, together with notes as to occurrence:

BAMBOO (*Bambusa vulgaris*).

Rust (*Uredo Paspalicola* P. Henn.). Not common.

Beans (*Phaseolus vulgaris*).

Anthracnose (*Colletotrichum lindemuthianum* [Sacc. & Magn.] Scrib.). Common, but less serious than last year.

Bacteriosis (*Bacterium phaseoli* Er. Sm.). Common, severe at times.

Crown rot (*Fusarium* sp.). A wet-weather disease.

Downy mildew (*Phytophthora terrestria* Sherb.) Serious in wet weather.

Gray leaf spot (*Isariopsis griseola* Sacc.). Varying with the varieties, has been very prevalent. On the numerous plantings observed about the Island it has been the most common bean disease.

Leaf spot (*Cercospora* spp.). Not common.

Powdery mildew (*Erysiphe polygoni* Dc.). Common on mature plants, causes no damage.

Rust (*Uromyces appendiculatus* [P.] Lk.). Common, causes some defoliation.

Beet (*Beta vulgaris*).

Leaf spot (*Cercospora beticola* Sacc.). One collection.

Carnation (*Dianthus caryophyllus*).

Rust (*Uromyces caryophyllinus* [Schrank.] Wint.). One collection.

Alternariose (*Alternaria dianthi* Stev. & Hall). One collection.

Cassava (*Manihot utilissima*).

Leaf spot (*Cercospora henningsii* Allesch.). Common, but not serious.

Celery (*Apium graveolens*).

Root-knot (*Heterodera radicicola* [Greef] Müll.). Has not been severe.

Chayote (*Sechium edule*).

Leaf blight (*Cercospora* sp.). Common, and the cause of the death of many plants.

Chinese Cabbage (*Brassica juncea*).

Root knot (*Heterodera radicicola* [Greef] Müll.). Not severe.
Leaf spot (*Cercospora bloxami* [Berk. & Br.]). Common.

Coconut (*Cocos nucifera*).

Leaf spot (*Pestalozzia palmarum* Cke.). Common.

COLEUS (*Coleus* spp.).

Root-knot (*Heterodera radicicola* [*Greef*] Müll.). Common and very injurious.

CORN (*Zea mays*).

Leaf spot (*Helminthosporium turcinum* Pass.). Two collections.

Rust (*Uredo pallida* Diet. and Holw.). Common but not serious.

Smut (*Ustilago zeæ* [Beckm.] Ung.). Of no economic importance, although of common occurrence.

COWPEA (*Vigna unguiculata*).

Leaf spot (*Cercospora cruenta* Sacc.). Several collections, sometimes causing defoliation.

CUCUMBER (*Cucumis sativus*).

Downy mildew (*Peronoplasmopora cubensis* [B & C.] Clinton). Very common and very serious.

Root-knot (*Heterodera radicicola* [Greef] Müll.). One report.

DATE (*Phœnix dactylifera*).

Leaf smut (*Graphiola phœnicis* [Moug.] Poit.). Common.

EGG-PLANT (*Solanum melongena*).

Crown rot (*Sclerotium Rolfsii* Sacc.). Serious in connection with *Heterodera*.

Fruit rot (*Phomopsis vexans* [Sacc. & Syd.] Harter. Common during a part of the yeaf.

Stem cankers, leaf spot (*P. vexans*). Very serious on some plantings.

Root-knot (*Heterodera radicicola* [Greef] Müll.). One report.

Wilt (*Bacterium solanacearum* Er. Sm.). Very serious at times.

FIG (*Ficus carica*).

Rust (*Kuehneola fici* [Cast.] Butler). Causes defoliation.

GANDUL (*Cajanus indicus*).

Rust (*Uromyces dolicholi* Arthur). Common.

GRAPEFRUIT (*Citrus decumana*).

Anthracnose, leaf spotting, wither tip (*Colletotrichum glocospo-*

rioides Penz.). Common, but causing slight damage only, except on trees weakened by other causes.

Damping off (*Sclerotium Rolfsii* Sacc.). One report of serious damage.

Foot rot (?). Continues to be prevalent in certain groves.

Frenching. Very common, more so than in previous years. High price of fertilizers may explain the situation in part.

Fruit rot, twig blight, gummosis (*Diplodia natalensis* Evans). As usual, causing very heavy losses in all forms.

Scab (*Cladosporium* [?] *citri* Mass.). The most serious disease of grapefruit, continues to spread and cause heavy loss.

Lettuce (*Lactuca sativa*).

Leaf spot (*Cercospora lactucæ* Stevenson). Reported as common.

Lima Beans (*Phaseolus lunatus*).

Rust (*Physopella concors* Arthur). One report.

Mango (*Mangifera indica*).

Blossom blight (*Colletotrichum glœosporioides* Penz.). Very prevalent, particularly in wet weather.

Leaf spots (*C. glœosporioides* Penz. and *Pestalozzia guepinia* Desm.). Exceedingly common.

Muskmelon (*Cucumis melo*).

Downy mildew (*Peronoplasmopora cubensis* [B. & C.] Clinton). Serious.

Gray blotch (*Mycosphærella citrullina* [C. O. Sm.] Gross. Threatens to be very serious.

Okra (*Hibiscus esculentus*).

Leaf blight (*Cercospora hibisci* Earle). Causes defoliation.

Orange (*Citrus sinensis*).

See also grapefruit.

Blossom end rot (*Fusarium* sp.). Quite prevalent.

Fruit rot (*Diplodia natalensis, Penicillium* spp.). The cause of very heavy losses, particularly the former.

Scaly bark (Cause unknown). Two cases under observation.

Papaya (*Carica papaya*).

Leaf spot (*Pucciniopsis caricæ* Earle). Very common, causing defoliation.

Trunk rot (*?*). Two reports.

Peach (*Amygdalus persicæ*).

Rust (*Tranzschelia punctata* [Pers.] Arthur). One report.

Peanut (*Arachis hypogea*).

Leaf spot (*Cercospora personata* [G. & C.] E.). Common.

Rust (*Uredo Arachidis* Lagerh.). Common.

Pepper (*Capsicum annuum*).

Anthracnose (*Glœosporium piperatum* Ell. & Ev.). Prevalent late in the season.

Crown rot (*Sclerotium Rolfsii* Sacc.). Not serious this season.

Leaf spot (*Cercospora capsici* H & W.). Attacks old plants, not serious, controlled by Bordeaux mixture.

Pineapple (*Ananas sativus*).

Fruit rot, butt rot of slips (*Thielaviopsis paradoxa* [De Seynes] Höhn. The cause of exceedingly large losses, particularly in the first form.

Rose (*Rosa* spp.).

Leaf spot (*Cercospora rosicola* Pass). Common.

Leaf spot (*Actinonema rosæ* [Lib.] Fr.). One report.

Sorghum (*Holcus sorghum*).

Rust (*Puccinia purpurea* Cooke). Common.

Sudan Grass (*Holcus sorghum* var.).

Rust (*Puccinia purpurea* Cooke).

Leaf spot (*Colletotrichum lineola*). Common.

Sugar Cane (*Saccharum officinarum*).

Leaf spots (*Leptosphæria, Helminthosporium*, etc.). Very prevalent in all parts of the Island.

Mottling (*?*). Epidemic in the western part of the Island.

Pineapple disease (*Thielaviopsis paradoxa* [De Seynes] v. Höhn.). Very common.

Red rot of the leaf sheath (*Cercospora vaginæ* Krüger). Very common everywhere.

Rind disease (*Melanconium sacchari* Mass.). Common but causing no damage except in isolated cases.

Root disease (*Marasmius sacchari* Wakker, *Himantia stellifera* Johnston). Very common and the cause of much loss.

Sweet Potato (*Ipomoea batatis*).

Rust (*Coleosporium Ipomœae* [Schw.] Burr). Common.

White rust (*Albugo Ipomœae-panduranæ* [Schwein] Swing). Common.

Sword Bean (*Canavali* sp.).

Root-knot (*Heterodera radicicola* [Greef] Müll.). One report.

Rust (*Cerotelium Canavaliæ Arthur*). Common but not serious.

Tobacco.

Leaf spot (*Cercospora nicotianæ* E. & E.). Very prevalent.

Mosaic (?). Common, but of importance for the most part on the smaller plantings.

Damping off (?). A very common trouble in the seed beds.

Tomato (*Lycopersicum esculentum*).

Anthracnose (*Colletotrichum phomoides* Sacc.). One report.

Blossom end rot (?). Not serious.

Black spot (*Phoma destructiva* Plowr). Occurred on one planting.

Buck-eye rot (*Phytophthora terrestria* Sherb.). Not serious.

Downy mildew (*Phytophthora infestans* [Mont.] Debary). One report.

Leaf mold (*Cladosporium fulvum* Cke.). Common on early plantings.

Leaf spot (*Septoria lycopersici* Speg.). Very common, causing defoliation.

Root-knot (*Heterodera radicicola* [Greef] Müll.). Serious.

Wilt (*Bacterium solanacearum* Erw. Sm.). One of the most serious diseases of this host.

Yautía (*Colocasia* sp., *y Xanthosoma* sp.).

El mal. (?) Several reports.